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Proceedings of the 2000

SOUTHEASTERN VHF SOCIETY CONFERENCE

April 14th and 15th, 2000
Atlanta, Georgia

Published by: ARRL The national association for AMATEUR RADIO

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Printed in USA

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ISBN: 0-87259-799-7

ARRL Order Number: 7997

First Edition

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Ansley L. Meaders

March 14, 2000

Dear Friends:

On behalf of the City of Marietta it is a privilege and a pleasure to welcome all of you to our community for the Southeastern VHF Society Convention.

Marietta has quite a variety of activities and sites to offer. I hope that during your stay here you are able to experience our Southern hospitality and charm that makes Marietta such a special place to live and work!

Best wishes for a successful convention and warmest personal regards!

Sincerely,

Ansley L. Meaders
Mayor

SVHFS SOUTHEASTERN VHF SOCIETY

Fellow members and guests of the Southeastern VHF Society

Welcome to Atlanta for a fourth year. We were pleased with the success of our earlier conferences and look forward to bringing you another. Thanks to all the presenters, participants and prize donors. We hope that everyone enjoys the presentations, the conference proceedings and has a very good time.

As others have correctly pointed out in the past, the real value of attendance is getting to know other died-in-the-wool vhfers that come from all over the world to these conferences. Of course the proceedings are great and useful tools for all of us, but it is hard to describe how valuable the one-on-one time is with the real "pros". It's really special to be able to talk with these folks about contesting issues, preamps, amplifiers, antennae, relay switching, phasing schemes, spectrum issues and new methods of operation.

So if you couldn't make it this year, we hope you'll be here next year.

Thanks to the ARRL for their assistance and for publishing the Proceedings. And thanks to everyone on the committee for countless hours of work and preparation for the conference!

73,

Dick Hanson, K5AND
SVHFS President
Conference Chairman

Bob Lear, K4SZ
SVHFS Vice President
Program Chairman

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FOURTH ANNUAL SOUTHEASTERN VHF SOCIETY CONFERENCE AGENDA
ATLANTA, GEORGIA APRIL 14-15, 2000

Friday, April 14

8:00 - 4:00	Registration
8:00 - 12:00	Antenna Gain Measurements in hotel parking lot Noise Figure Measurements in conference room
8:00 - 9:00 PM	Vendor Product Displays
12:00 - 1:00	Lunch (on your own)
1:00 - 1:15	Welcome and Announcements: Dick Hanson K5AND, SVHFS President - Conference Chairman Bob Lear K4SZ, SVHFS VP - Technical Program Chairman
1:15 - 1:45	"Adding a Transverter Port to a Yaesu FT 920" Bob Lear K4SZ
1:45 - 2:30	"The Pisgah Astronomical Research Institute or Why do I keep running into the same folks wherever I go?" Charles Osborne, WD4MBK
2:30 - 2:45	Break
2:45 - 3:15	"An Accurate Low Cost Auto-Tracking System for EME" Bob Taylor, W5LBT
3:15 - 4:15	"Some Thoughts on VHF TVI and RFI" Ray Rector, WA4NJP
4:15 - 4:30	Break
4:30 - 5:30	SVHFS Annual Business Meeting and BOD election
5:30 - 7:00	Dinner (on your own)
7:00 - 9:00	Flea Market
9:00 - 10:00	SVHFS Board of Directors Meeting
10:00 - 12:00	ARRL VEC License Exam Session (old rules)
12:00 - 1:00 AM	ARRL VEC License Exam Session (new rules)

FOURTH ANNUAL SOUTHEASTERN VHF SOCIETY CONFERENCE AGENDA

Saturday, April 15

8:00 - 12:00	Registration
8:00 - 5:00	Vendor Product Displays
8:15 - 8:30	Conference Welcome - Dick Hanson K5AND, SVHFS President
8:30 - 9:15	" Six Meter Yagi for Contesting and Expeditions" "Rotating Mast for Expeditions and Mountain-Topping" Dick Hanson K5AND
9:15 - 10:15	" VHF DXpedition - You can do it" Chris Patterson, W3CMP
10:15 - 10:30	Break
10:30 - 11:00	"Aligning Preamps Using an FM Receiver" Bruce Randall, WD4JQV
11:00 - 11:30	"A Switchless Transverter - Transceiver Interface" Reed Fisher, W2CQH
11:30 - 11:45	"SVHFS Conference Noise Figure Measurements" "SVHFS Conference 2000: Pre-Amp Gain and NF Results" Fred Runkle, K4KAZ and Jim Worsham, W4KXY
11:45 - 12:00	"Antenna Gain Measurement" "SVHFS Conference 2000: Antenna Gain Results" Dale Baldwin, WB0QGH
12:00 - 1:00	Lunch (on your own)
1:00 - 1:45	" Some Notes on Shielding, TVI and Reverse TVI" Ruddy Ellis, W4LNG
1:45 - 2:30	" Tower and Antenna Construction Techniques" Tom Whitted, WA8WZG
2:30 - 2:45	Break

2:45 - 3:15	" Directional Couplers and their use in Amateur Radio" Bruce Randall, WD4JQV
3:15 - 4:15	"A Guided Tour of Down East Microwave" Steve Kostro, N2CEI
4:15 - 4:30	Break
4:30 - 5:30	SVHFS Auction
6:00 - 7:00	Cash Bar
7:00 - 10:00	SVHFS Banquet: Guest Speaker - Joel Harrison W5ZN 2000 K4UHF Award announcement Prizes, Prizes, Prizes !!!

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Adding a Transverter Port to a Yaesu FT 920

Bob Lear K4SZ

After successfully adding transverter ports to my Icom 736 HF+6m transceiver and publishing the results in the 1999 SVHFS Conference Proceedings, I wanted to do the same to another of my HF rigs, the Yaesu FT 920. This was really an even more attractive IF rig to me because of the built in DSP, a feature that I have grown to really use and appreciate. The FT 920 does have a receive antenna input, but not a transverter TX port. Even though the output power can be lowered to about 10W and by using an inline attenuator pad the FT 920 can be used with split IF transverters, but one still has to remember to turn down the output power on the transceiver to minimum. I know how easy it is to forget this important step as I'm sure many others have discovered. I did use the FT 920 with 2m and 220 DEM transverters that way for some time before finally doing this modification. True transverter ports are much more desirable, both from the operational and protection standpoints. After my experience with the IC 736, I incorporated some of the same ideas, but I didn't really worry as much about being so non-invasive this time. The modification could be done in a similar non-invasive way as described for the IC 736. I did decide to use the same method as before in order to not cut internal coaxes in the FT 920. I also left more permanent evidence this time as two holes were drilled in the rear panel of the radio, but I think the looks are acceptable and the added convenience will make the radio even more useful to me.

After checking the schematic and looking in the unit, I found miniature coaxes with connectors between the driver TX output on the main board and PA unit board on the transmit side and between the LPF unit and the receive RX input to the main board on the receive side. This is the same place the RX antenna input enters the main board with either RX normal or RX ANT selected by a miniature relay on the main board. By using coax with the miniature connector plugs and jacks, then the original coax jumpers within the radio won't have to be cut. The miniature coax with installed connectors and the mating PC mount jacks are the same as used in Icom radios and should be available from Yaesu or Icom as replacement parts. They are also available from Ten-Tec where they are used in the VHF transverter kits: 35225 PC mount Jack and 86071 RG 174 coax (9 inches) with installed connector, about $4 for a set. Only one pair is needed for this project. The other parts needed are a micro-mini DPDT toggle switch, RS 275-626 , a RS 275-241A SPDT micro-miniature relay (or other brand), some hook up wire, heat shrink tubing, and a chassis mount BNC connector.

Two holes need to be drilled in the rear panel of the radio. To the right of and aligned with the RX antenna IN jack, drill a 3/8" hole (or hole for your chassis mount BNC connector, but not larger than 3/8" because of internal clearances) with the same horizontal spacing as the RX antenna jacks. I chose to put the transverter in/out switch in the next available space to the left of the DATA jack. This hole is only 3/16 if you use the same sub-miniature switch I did. Drop it below the line of rear panel jacks so that it has clearance with the circuit board in the radio. The additions are shown in Figure 1. These two holes will also require half circle clearance cut-outs in the radio case. If you do this carefully, they look very similar to the clearance cut-out for the DATA jack and quite natural when the project is completed as shown in Figure 1.

The schematic diagram, Figure 2, shows the wiring required. The relay can be pre-wired with the piece of 86071 coax cut to about 4 inches, the other half of the piece of coax, a 35335 jack and a pair of wires from the relay coil to go to the transverter in/out switch where the 12 VDC will be supplied. The second set of contacts on the switch is used to interrupt the T12 line coming from J1014 on the main board before going to the LPF and PA units. This shuts the PA unit off during transverter operation although since there is no drive, there will be no output. By lifting the T12 line, the fan is also shut off during transmit as it is not needed with the PA unit off. 12 Volts DC is also available on J1014 and hook up wire is run from there to the back panel switch location to supply the relay DC and the T12 line interrupt. I did cut the T12 wire to go to the switch and from the switch back to the remaining T12 wire to the LPF unit. The 12 V hook up wire is just soldered to the back of the pin at the connector plugged into J1014 and can be easily removed if desired. J1014 is conveniently located just behind the DATA jack and close to where all the wiring is done as seen in Figure 3.

The relay is mounted with double-sided foam mounting tape to the side of the chassis. The existing coax is unplugged from J1001 and plugged into the jack mounted on the relay common pin. Put some epoxy on the rear of the jack to make it more secure to the relay case. The coax from relay pin NC then goes to J1001 for normal operation and the coax from relay pin NO goes to BNC connector added to the rear panel for transverter operation when the relay is energized.

Figure 4 shows the modified transceiver connected to a DEM transverter. When the added transverter switch is on (UP) then the internal coax to the transverter TX port is connected to the TX output on the main board. By connecting the transverter RX port to the RX antenna IN jack on the rear of the radio and the RX ANT front panel switch selected then the main board TX and RX are connected to the transverter. Additionally, when the transverter switch is on the T12 line is opened, turning off the unused PA and un-needed fan during transverter operation. When the switch is down (OFF) and the RX antenna deselected the transceiver is returned to normal operation. This is now identical to transverter operation with a Yaesu FT 1000MP except the transverter switch to connect the rear panel TRV TX is on the rear panel on the FT 920 instead of inside the top cover trap door on the FT 1000MP.

The driver output from the PA is about 20 mW (13 dBm) and can therefore be used directly with a DEM transverter. This makes the FT 920 into a first class transverter IF rig which can be returned to normal HF or 6m use with just the touch of a button and a switch and no worry about transmitting power into the transverter. After further consideration, I have decided that I would really rather have done the modification like I did to the IC 736, switching both TX and RX lines from the main board, so that transverter operation could be selected with only one switch rather than two. This would make it much easier to use the 920 on both 6m and 2m for example. I guess this means I'll have to get another FT 920 just to try out the ideas unless I undo this mod and start over. It would be even better if the transverter switch could be availble on the front panel. I am planning that as my next project for both my FT 920 and FT 1000MP. Now to decide which front panel switch function to sacrifice and how to get to it!

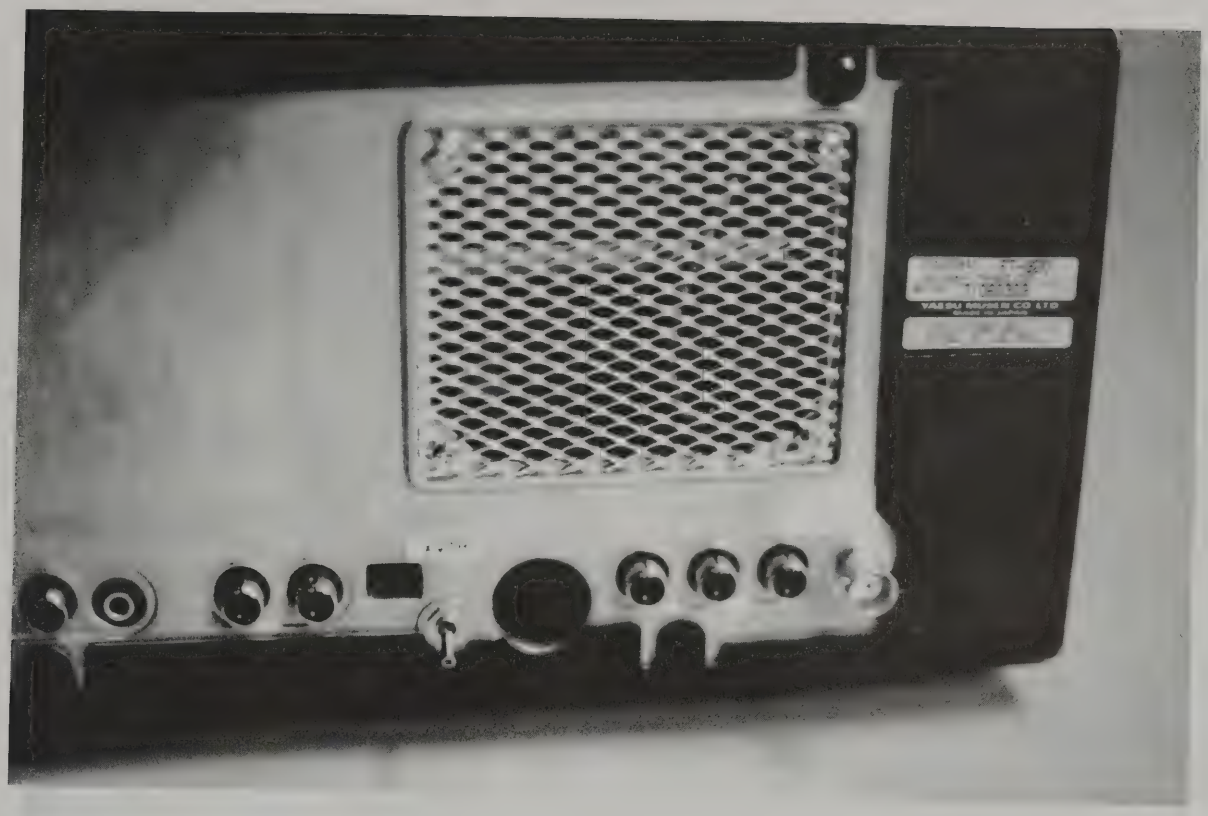


Figure 1 Completed rear view showing added BNC connector and switch

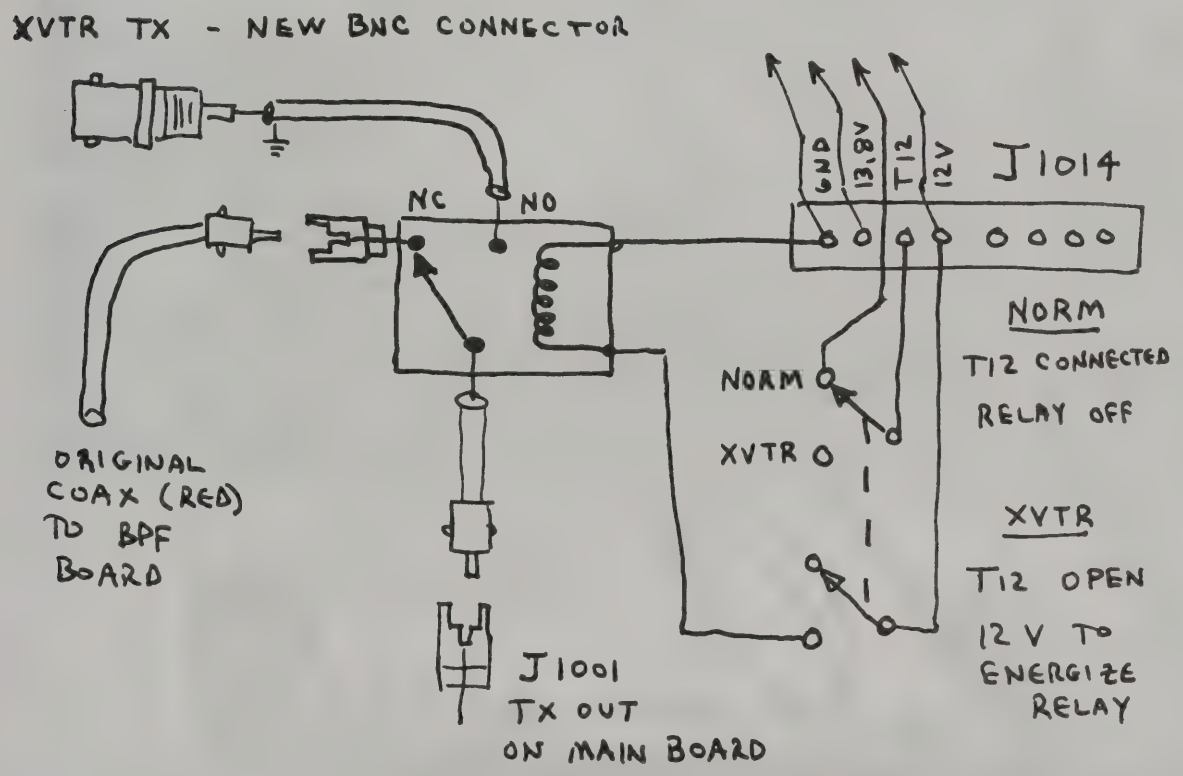


Figure 2 Schematic diagram of wiring modifications

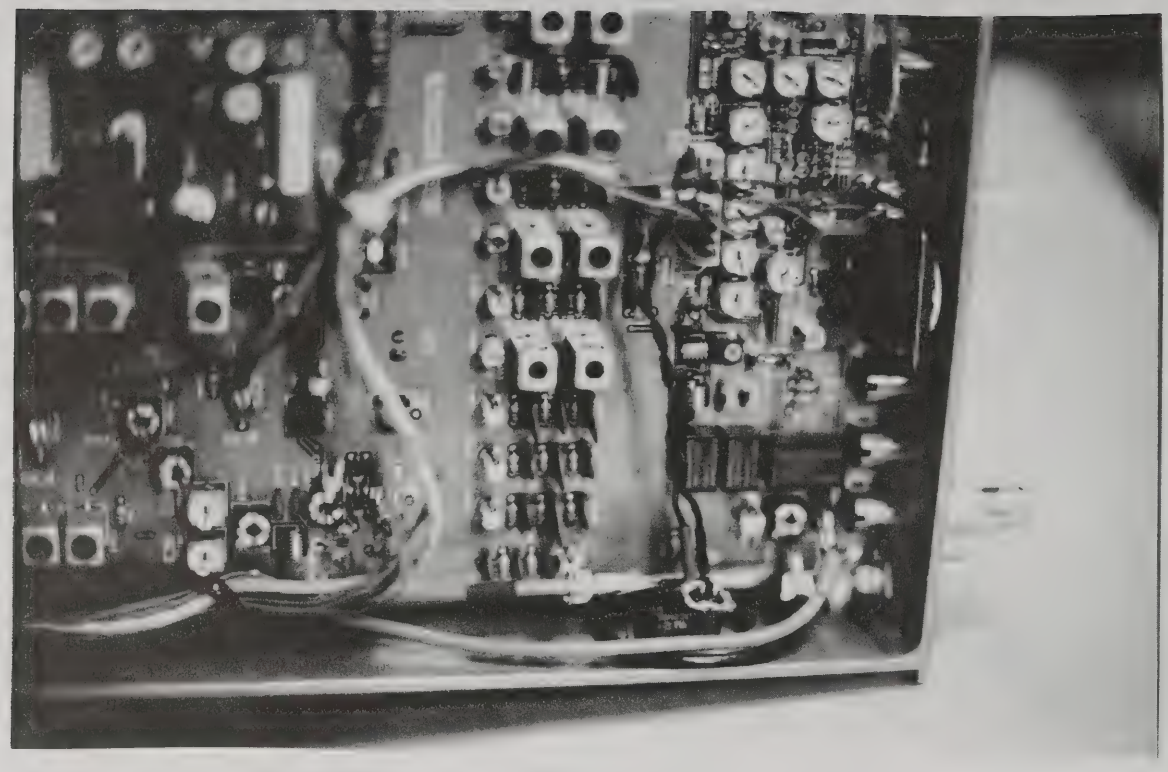


Figure 3 Completed interior view

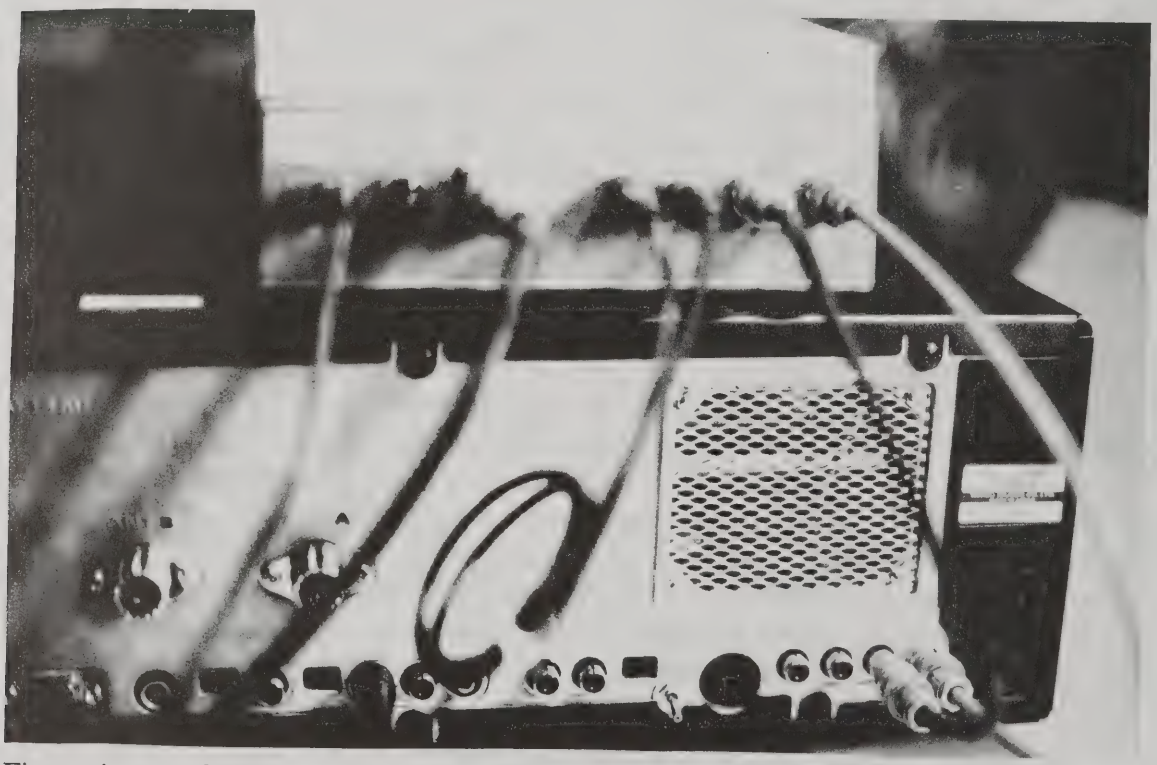


Figure 4 Completed rear view with transverter connected

The Pisgah Astronomical Research Institute
or
Why Do I Keep Running Into These Same Folks Where Ever I Go

PARI

The Pisgah Astronomical Research Institute was formed in 1999 as a 501c3 not for profit public foundation dedicated to science education. PARI's facility presently supports research in radio and optical astronomy for colleges and universities in the surrounding southeastern states.

History

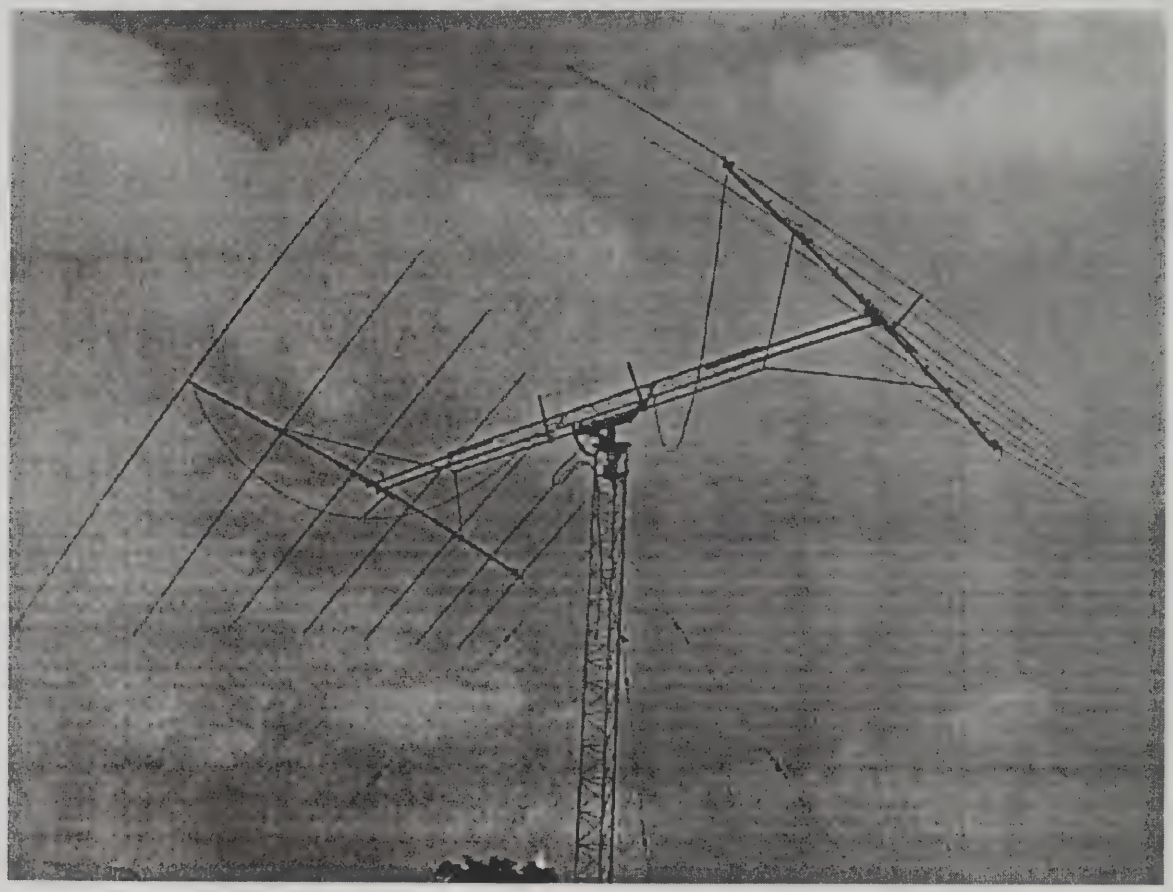
In 1963 several hundred acres of the Pisgah National Forest were deeded to NASA for the construction of the Rosman Tracking Station. For the next twenty years the facility supported satellite and manned spaceflight mission command, control, and telemetry operations. Two 85ft antennas capable of tracking low Earth orbit, fast moving, spacecraft form the centerpiece of the facility's antennas.

By 1983 NASA had established a network of geosynchronous telemetry and data relay satellites, making obsolete the dozens of tracking stations scattered across the globe.

Many were deeded to Universities in their home countries. Others were simply closed and the equipment scrapped. Rosman met a different fate.

The cold war and a growing need for electronic intelligence gathering led to the NASA facility coming under Department of Defense control as the Rosman Research Station. More buildings and antennas were added until the site had 350 employees supporting 20+ antennas. With approximately 100 people on the round the clock security forces, secrecy was assured.

With the end of the cold war, and pressure for base closings, the Rosman Research Station was deeded back to the Forestry Service in 1995. Through a complex land swap transaction the facility was obtained to become the Pisgah Astronomical Research Institute in January of 1999.



PARI's First Year

Throughout 1999 PARI was undergoing a gradual renovation to support its new educational mission. The security building and two double wide trailers were converted into dorm space. The two 85ft antennas received modernized position encoders, and preparations are underway for new DC slow motion motors. A pair of 7 element 17-30 MHz M-Squared log periodic yagis were installed to receive the decametric emissions

from Jupiter. Our 4.6m antenna was converted to 1420 MHz hydrogen emission line use. And the first 26meter antenna was also outfitted with a 1420 MHz front end.

PARI had a wide variety of fiber optic cabling already installed to support its massive data infrastructure. Throughout the first year this fiber network was upgraded to be used as a 100 mbps PC network. 14,000 feet of fiber was relocated from an abandoned antenna site to serve the main complex's data network.

One of the first University groups to become involved with PARI is UNC-Chapel Hill. A NASA project to search for low mass stars (between the size of Jupiter and our Sun) was begun with the construction of a 10ft diameter telescope dome. An automated telescope will be placed in the dome. A 100baseFX network connection brings commands to the telescope and returns data to the server for consolidation on CDRoms. Using a search routine, the whole sky will be mapped several times per night. Then variations in brightness will be sought which might indicate a binary star system. These candidate star systems will then be passed to a larger telescope for further study. The telescope at PARI will generate 3.2GB of image data on a clear night.

Volunteers

PARI's present staff consists of four long time employees of the Rosman Research Station plus three new employees. As one might expect, the task list is long. As with many not-for-profit endeavors, PARI would not be possible without the help of Volunteers. Fortunately PARI encompasses a beautiful environment in the North Carolina mountains unusually rich in engineering intrigue.

Why Do I Keep Running Into These Same Folks Where Ever I go

PARI's volunteer efforts highlighted an interesting aspect of the type person attracted to these situations. Time and again I was running into the same people in different unrelated groups. Whether it was: ham radio, hiking, photography, astronomy clubs, high power rocketry gatherings, air shows, or computer club meetings, our circle of friends kept intersecting. Indeed new Volunteers at PARI invariably shared a few of

this same collection of hobbies, making for lively story telling around the dinner table, and an instant rapport with people you've never worked with before.

One thing common to all these hobby areas is a search for personal challenges. Radio astronomy is perhaps one of the most challenging of engineering endeavors. It is said that if all the energy of all the radio telescopes in the world were summed together, it would still not be as much energy as a single snowflake hitting the ground. It is quite exciting to build equipment sensitive enough to sift this tiniest of watts from the radio noise around us, and display it as an overlay on a map of the surrounding galaxy. It is proof positive that what we see is coming from tens of thousands of light years distant. Hams love DX and this is certainly the ultimate in DX. For the volunteers this group effort allows for far greater challenges of construction than would be possible individually.

A typical volunteer weekend is hosted once or twice a month. It starts Saturday morning about 10am with volunteers from places like: Atlanta, Charlotte, Greenville SC, and Knoxville TN converging on the site to help with a wide variety of tasks including: computer network, programming, control systems, webcams, fiber optics, tracing wiring, remove unused cabling under the floors, radio astronomy receiver test and configuration, and just general cleanup of the lab and control room areas. After a hard day of this type work we typically have a cookout and then adjourn to PARI's helicopter pad to setup for some astronomy. PARI's dark skies are a welcome change for many of the group living too close to major metro areas. Many of the group of Volunteers camp out near the helipad, weather permitting. Others stay in the old NASA wing of the main operations building. A sleeping bag and air mattress is about all that is required.

As of early February 2000, PARI's Volunteer email list included 115 people in 10 or 12 states. To join the volunteer group email list, send a message to PARI Technical Director, Charles Osborne at: cosborne@pari.edu or call 828-862-5554. Also check out our website at http://www.pari.edu . We appreciate all the help we can get in this unique endeavor. All we can guarantee is that you'll spend some quality time in an intriguing place, learning new things, with great people of similar interests.
73. Charles Osborne, WD4MBK

AN ACCURATE LOW COST AUTO-TRACKING SYSTEM FOR EME

BOB TAYLOR W5LBT **G. WILLIAMSON K5GW**

There currently are several types of Moon tracking systems being used by EME'rs. These include the use of reed switches, potentiometers, and optical encoders.

The system described in this paper uses an ABSOLUTE optical encoder. The main advantage being that once the encoder has been mechanically coupled to the antenna, there is no need for readjustment for power outages, etc. If there is a need to make an adjustment, it can be easily done thru the computer software. Another feature of the system is the simplicity (see photo) using only one small circuit board for each digital encoder. The power requirement is 12 volts at about 50 milliamperes. The personal computer required can even be an old 286 and the software will work in either a DOS or Windows environment. The operation of the system is thru computer software and the control of the system is thru one of the computer COM ports. The data link between the COM port and control board is at the low baud rate of 1200, which allows the use of inexpensive cable between the antenna and the ham shack.

SYSTEM DESCRIPTION:

The encoder output is 10, 12, or 14 bit binary (GRAY CODE) data, which is fed to the control board in parallel form. The control board microprocessor converts the parallel data to series data which is sent to the computer RS 232 port (COM port). This data is then compared to the actual moon position information. The encoder data gives us combinations, which provide a resolution (accuracy) of plus or minus .18 degrees with 10 bit, .09 degrees with 12 bit and .022 degrees with 14 bits.

On the control board, the main component is a Micro Chip Corp. PIC16C55-XT/P which is a programmable 8 bit microprocessor (PIC) with 16 I/O ports .We use bits as necessary for the encoder data, and 2 bits for the motor control the other are used for addressing extra PC Boards. The PIC also has a bi-directional series port (RS 232) for communication with the computer. The output of the control board is thru two reed relays. These provide isolation and are capable of driving any type of motor relay that may be used.

In a typical antenna system where there are both azimuth and elevation motors, it is necessary to have an encoder and PC control board for each. Where the antenna is operating on a polar mount, only one encoder and control board is required if the operator manually adjusts for the declination change from day to day. Up to 16 encoder/control boards can normally be connected in parallel and controlled by one computer when there are additional antenna systems in use.

OPERATION:

Once the encoder has been mechanically coupled to the antenna and wired up to the computer and antenna drive motor (see figure 1), the computer setup program can be initiated. The setup program allows you to do the following:

1. Input your Call, Lat, and Long
2. Input what mode(s) are to be used. ie; azimuth, elevation, GHA. Always answer Y or N
3. Input if you need to reverse reading
4. Input any calibration, (difference between error and what it should be).
5. Input any amount of "OFFSET" that is needed due to a mechanical difference that may have been introduced when the encoder was physically connected to antenna.
6. input for delays 300, 300, and 300 ;the Div will be 5, 5, and 5.
7. Lastly which Com Port to use.

ANSWER ALL WITH SOMETHING BLANKS DON'T WORK

The above information is entered only once and is maintained in a data file that is automatically accessed each time the computer is turned on. It can be easily changed if ever required.(see figure 2)

Moon data info (azimuth, elevation, declination, and GHA) is calculated every second in the software and continually displayed on the computer screen in real time. In addition, the actual encoder(s) position and the difference between the encoder(s) position and actual Moon position are displayed in real time. (See figure 3) Once every minute the Moon data is compared to the encoder data and if there is a difference, the motor is turned on for the time necessary to correct the error. This timing can be increased

It is recommended that the encoder and control board be contained in a metal box for shielding purposes. Sheet metal boxes and diecast aluminum boxes have proven quite adequate even in maximum power RF fields on 144 MHz.

Many thanks to VE7BQH, W7GJ, and W7QX for their testing, evaluation, and input given on the system and the software written by K5GW.

System components (encoders, control boards, and software) are available from **W5LBT. Bob Taylor** w5lbt@home.com

The Encoders Output is fed into circuit board through a 12/14 position Terminal Barrier, and then passes through a 620 ohm resistor that protects the micro chip. A +5 volt pullup is added to line to create a positive position. There are two unused pins that can be added for 14 bit Encoders. The signal is then routed to its' respective spot on the

Microchip. This signal is sent to your computer as parallel Gray Binary. Within the on board software it is converted to a parallel serial output. This is received by your computer and converted to Degrees. Resolution depends on what Encoder you are using.

Any Encoder that has an output of Gray Code can be used; you only need to order the software for that Encoder. All circuits boards are identical.

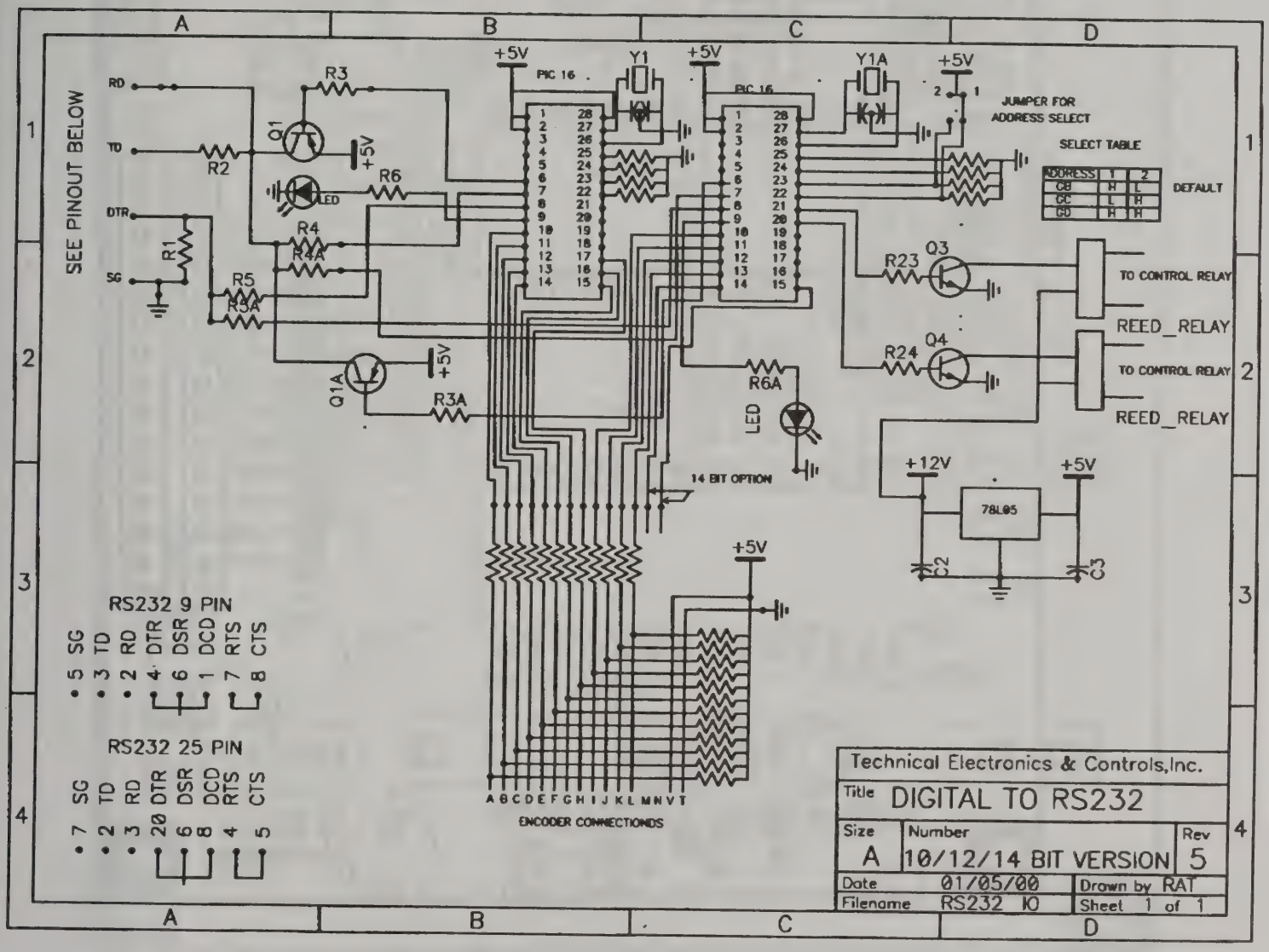
In the case of the latest version, the PCB has two microchips. Each micro will handle necessary amount of bits for your system., they are operating in unison. The second micro has to be address through two jumper blocks , marked High and Low, see truth table on drawing.

The last two bits on the second micro are used for controlling two reed relays. These are to switch outboard relays for motors.

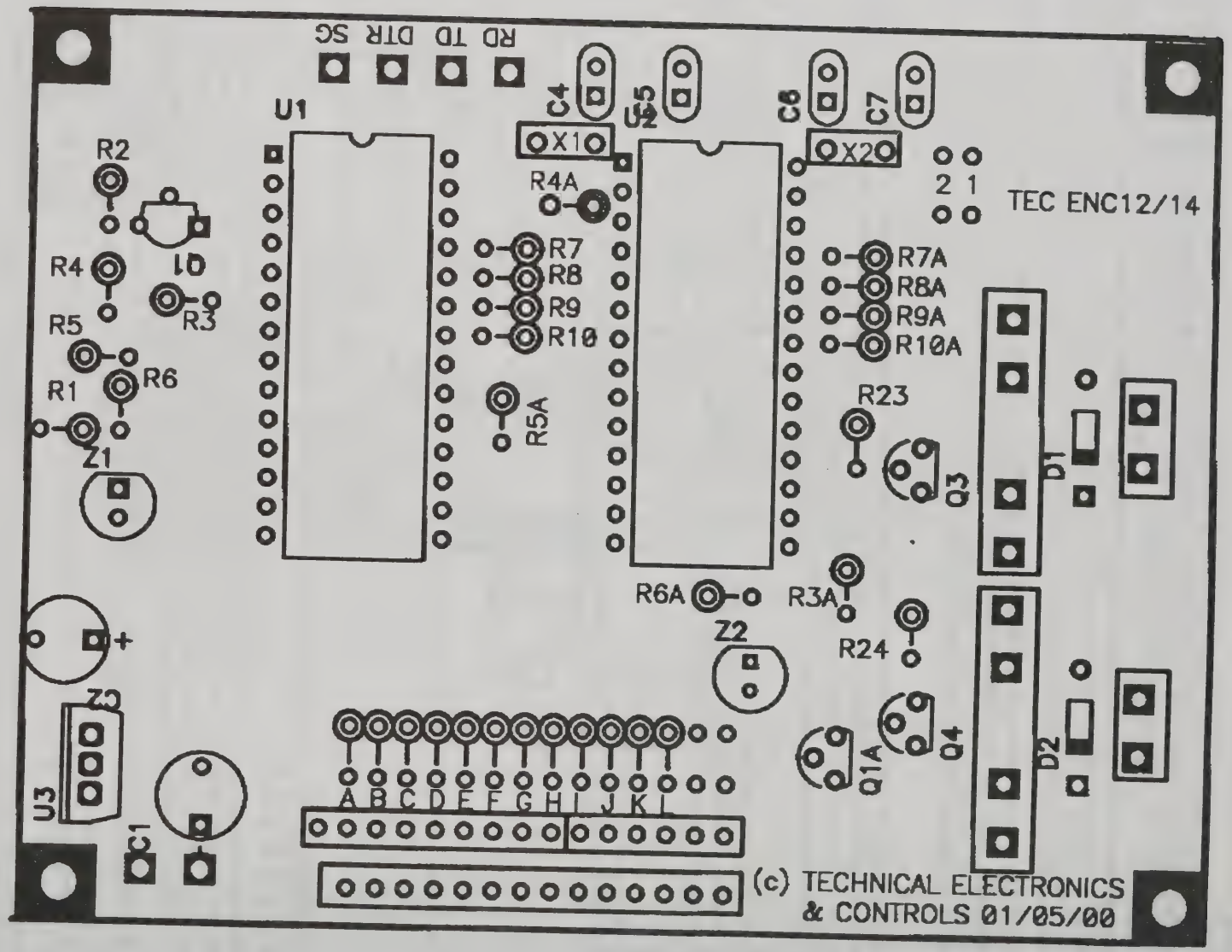
The software asks for an update every minute and this can be changed to a lesser amount.

The RS232 signal is fed through a shielded 6 wire cable (preferred) and the PCBs put into a die cast box. Using this , no experience has been encountered using High Power RF.

The cabling must be wired as drawing for RS232.



NEW 10/12/14 PCB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U1
U2
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C5
C8
C7
X1
X2
2 1
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R5
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R6
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R7A
R8A
R9A
R10A
R23
Q3
D1
R6A
R3A
Z2
R24
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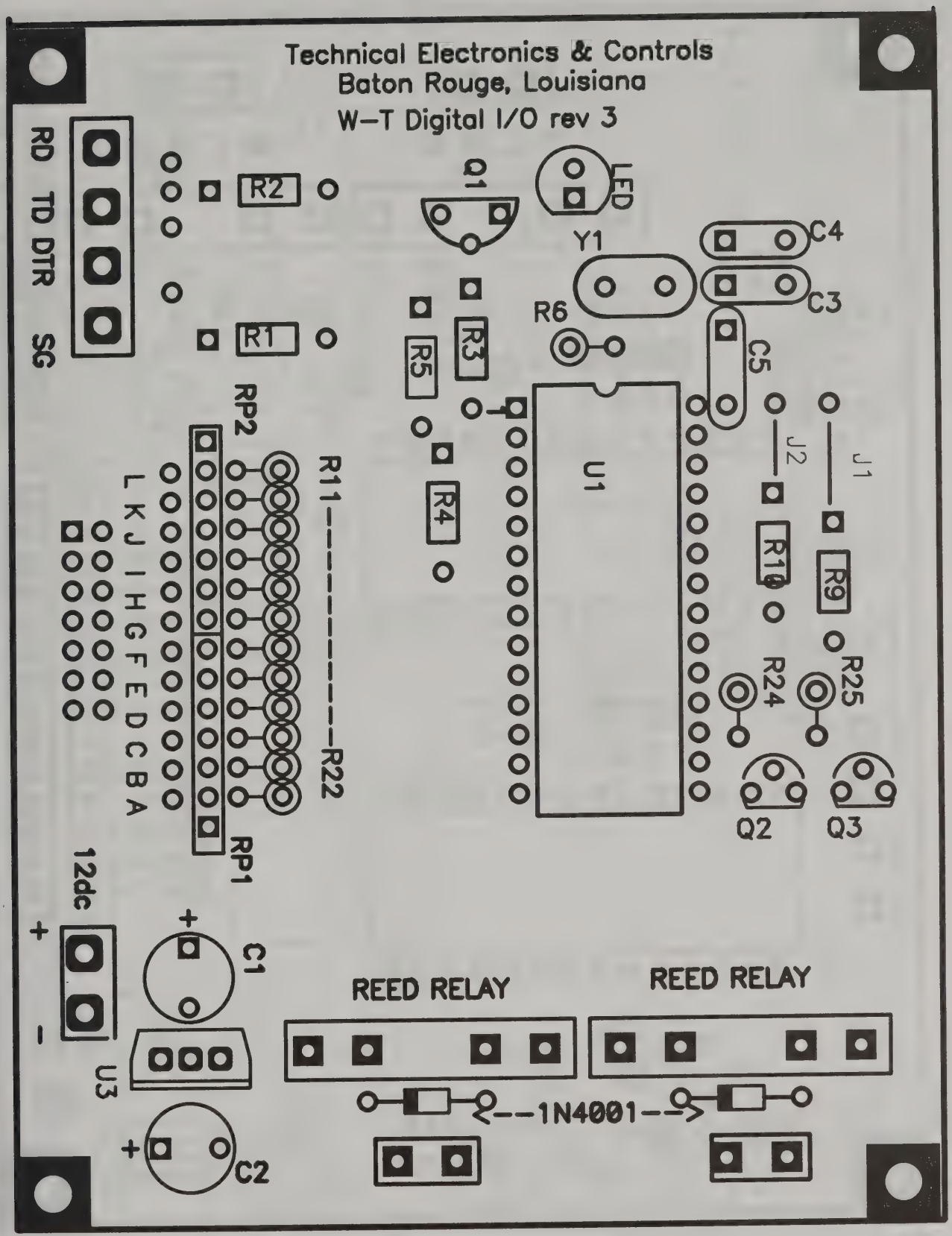
(c) TECHNICAL ELECTRONICS
& CONTROLS 01/05/00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REED RELAY
1N4001

TEC ENC12/14
(c) TECHNICAL ELECTRONICS
& CONTROLS 01/05/00
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R10A
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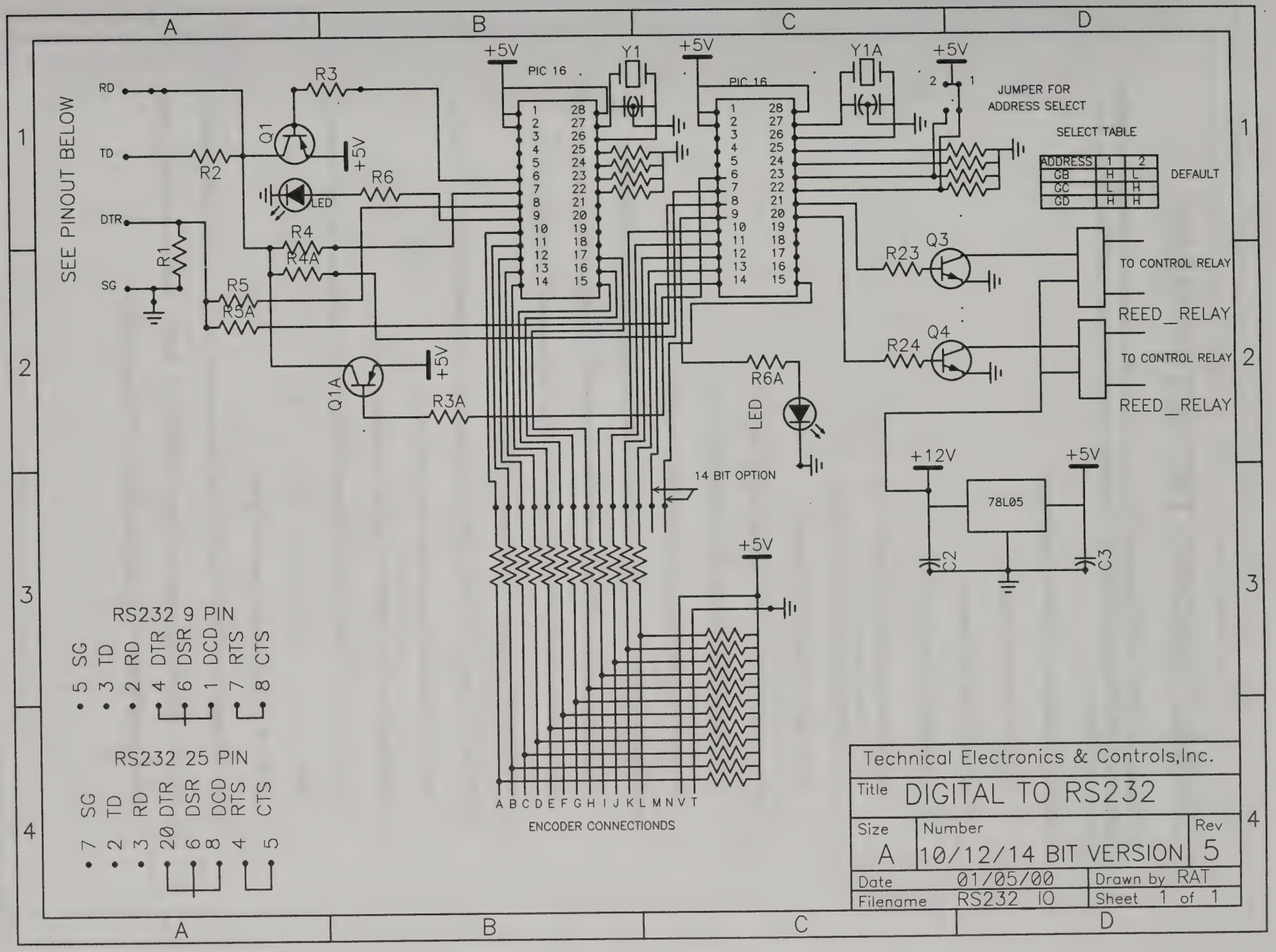
SEE PINOUT BELOW
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SG
R1
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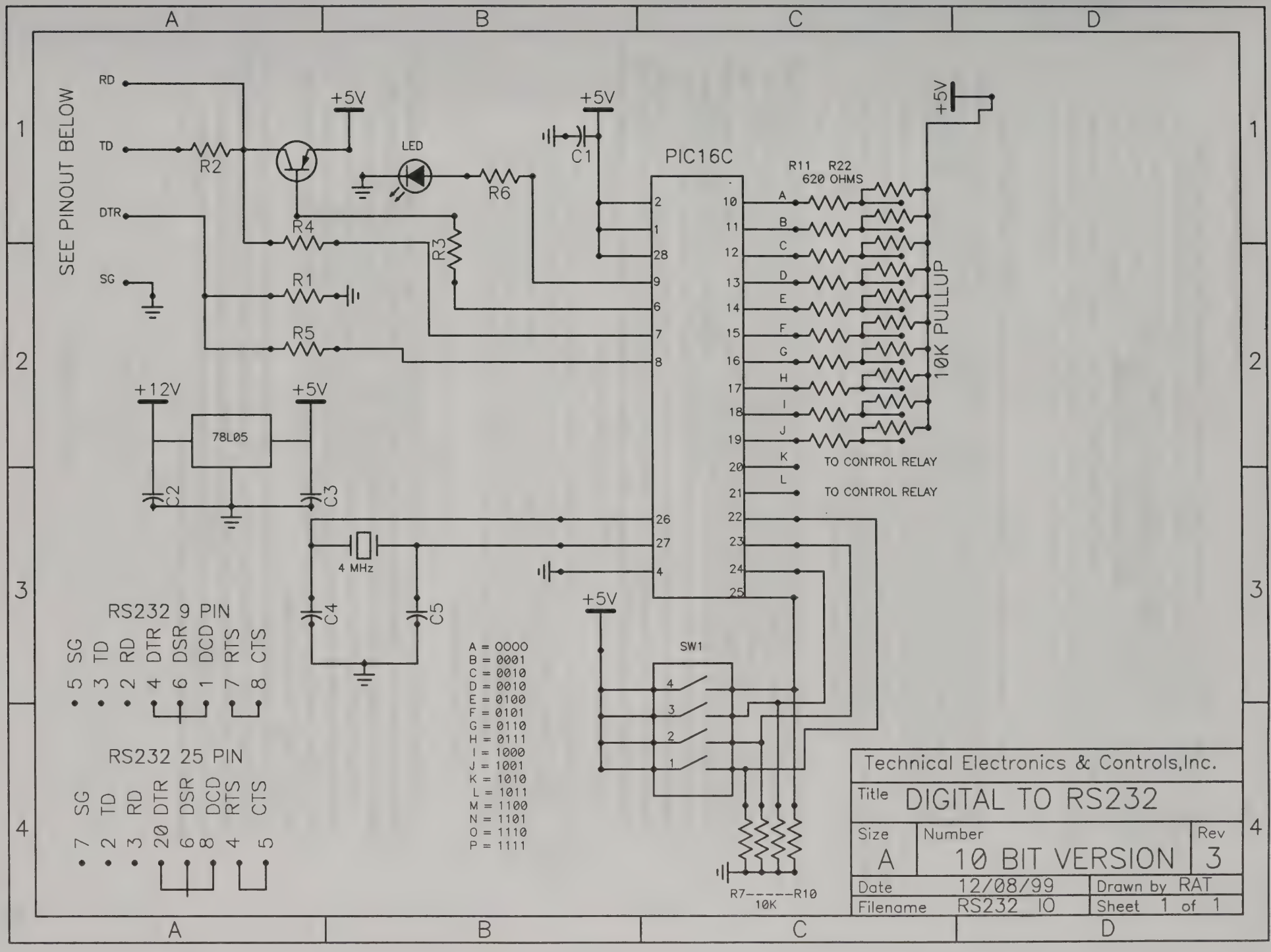
R3
R4
R4A
R5
R5A
R6
Q1
LED
+5V
Q1A
R3A
PIC 16
Y1
Y1A
JUMPER FOR ADDRESS SELECT
SELECT TABLE
ADDRESS 1 2
GB H L
GC L H
GD H H
DEFAULT
Q3
R23
Q4
R24
TO CONTROL RELAY
REED_RELAY
TO CONTROL RELAY
REED_RELAY
R6A
LED
14 BIT OPTION
+12V
78L05
C2
C3
RS232 9 PIN
5 SG
3 TD
2 RD
4 DTR
6 DSR
1 DCD
7 RTS
8 CTS
RS232 25 PIN
7 SG
2 TD
3 RD
20 DTR
6 DSR
8 DCD
4 RTS
5 CTS
A B C D E F G H I J K L M N V T
ENCODER CONNECTIONDS
Technical Electronics & Controls,Inc.
Title DIGITAL TO RS232
Size A
Number 10/12/14 BIT VERSION
Rev 5
Date 01/05/00
Drawn by RAT
Filename RS232_10
Sheet 1 of 1

UNDERSTANDING THE SETUP MENU

By selecting the SETUP OPTION in the MENU, you will be able to enter any changes from left to right after PRESSING the <C>HANGE To advance without changes to each item you may just press the ENTER key.

Each selection must have an answer. See sample.

1. **The Call Letters to be used.**
2. **The LAT for that Station.**
3. **The LONG for that Station.**
4. **Do you wish to read the AZ enter 'Y' or 'N' if not.**
5. **Do you wish to read the ELEV as above?**
6. **Do you wish to read GHA as above?**
7. **Do you wish to REVERSE THE READINGS for AZ?**
8. **Do you wish to REVERSE THE READINGS for EL?**
9. **Do you wish to REVERSE THE READINGS for GHA?**
10. **The next three ITEMS are very good. They allow you to set the Antenna to a known position, I use a SUN LINE on my Meridian. On the RUN MENU there is a column for each with ERROR attached, You can CALIBRATE your Antenna and ENCODER here for Any Encoder. Just insert the amount of ERROR +/- and that is it.**
11. **The AZ, EL, and GHA TIM is TIME in mill-seconds that it takes for motor to come up to speed, a propitch will require more that small rotors.**
12. **The Next three is the amount of travel in Degrees per Second.**
13. **The CNTL A REV and CNTL B REV are to change direction of the output from arrow keys.**
14. **AS stated which COM port you wish to use.**
15. **The last inputs are if the any ratio in travel versa antenna position. Set to (1) ONE initially.**
16. **After all selections have been made press <SAVE> then <EXIT> to return to previous menu. If you change Date or Time your must Press <SET> then <EXIT>.**


SEE PINOUT BELOW
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SG
R1
R2
R3
R4
R5
R6
LED
+5V
+12V
78L05
C1
C2
C3
C4
C5
4 MHz
PIC16C
R11 R22
620 OHMS
10K PULLUP
TO CONTROL RELAY
TO CONTROL RELAY
SW1
R7-----R10
10K
RS232 9 PIN
5 SG
3 TD
2 RD
4 DTR
6 DSR
1 DCD
7 RTS
8 CTS
RS232 25 PIN
7 SG
2 TD
3 RD
20 DTR
6 DSR
8 DCD
4 RTS
5 CTS
A = 0000
B = 0001
C = 0010
D = 0010
E = 0100
F = 0101
G = 0110
H = 0111
I = 1000
J = 1001
K = 1010
L = 1011
M = 1100
N = 1101
O = 1110
P = 1111
Technical Electronics & Controls,Inc.
Title DIGITAL TO RS232
Size A
Number 10 BIT VERSION
Rev 3
Date 12/08/99
Drawn by RAT
Filename RS232 10
Sheet 1 of 1

Some Thoughts on VHF TVI & RFI

Ray Rector - WA4NJP

April 2000

1) TVI and RFI starts at home and if you can not cure it at home there probably will not be much chance of curing it at your neighbor's. Until you can operate in a normal manner and not interfere with your home entertainment equipment there is not much need in trying to cure problems elsewhere. The curing of the problem at home will let you know where most of the particular problems are and how to address them. Some of the first things you need to know are:

What is being interfered with?
What fundamental frequency is causing it?
By what propagation method(s)

There have been several very good articles on TVI and RFI published in the past. In the 1997 SVHFS proceedings an article by Reed Fisher discuses some of the filtering hardware and the mechanics of the modern day TV. He included some very good designs for various filters. This is required reading if you have TVI problems. What I intend to do is try to take it a step further. How to put this information to use in a logical manner and where to start first. It IS NOT up to us as amateurs to modify, repair or replace other people's equipment, but we have to be able to show that when we are operating that we DO NOT interfere with the entertainment equipment at our own home. Sometimes this is difficult to do but if you can not show this in real operating, you will have trouble. With a bit of logic and sometimes a lot of work it can be done. By using the following suggestions and the information referred to you. You should be able to logically diagnose almost any TVI / RFI problem that may arise.

2) How is TVI & RFI created?

A. Harmonic generation

a. direct from transmitter

The direct radiation of harmonics will cause TVI, unless there is no one close enough to interfere with or the level is very low. If we all lived in the middle of a desert where there were no one to bother, then there would no reason to try to solve the problem that plagues most of us at least some of the time.

Reducing the level of harmonics can be accomplished at the source but most of the time it is an after generation problem that we try to fix. If the engineering in all the VHF transmitters were done properly there would be no harmonics to start with, but this not being true, there is going to be a level of harmonic energy to contend with.

The use of a well-designed low pass filter will reduce the level of harmonic energy. Sometimes it may be necessary to use several types of filters in the transmitting system. The placement of filters between the exciter and the power amplifier also may be necessary. Place filters between the power amplifier and the antenna, being very careful and sure that they are last, especially after any power measuring equipment that contains solid state devices.

b. Some other non-related source

After you are sure that the problem is corrected at the source be sure to check for other sources. The generation of harmonic energy can and is often generated in a non-related device. We have all heard that it can be generated in some corroded junction of a gutter or other metal devices. Do be on the look out for this but the odds are it is being generated in the front end of another transceiver, receiver or some solid state device that is connected to another antenna in the strong field of the fundamental transmitter. Proper placement of filters at this generation point, or a means to keep it disconnected during fundamental operation will clean this area up. It might be wise to check all other equipment for this type of harmonic generation by disconnecting each one, one at a time and observe the results.

B. Fundamental overload

The power output and close proximity to electronic entertainment equipment sometimes leads to fundamental overload. This can happen regardless of how strong or weak the signal strength is on the affected piece of equipment. The overload threshold of most TV's is independent of the strength of the signal being received. The only way to prevent this is to remove the fundamental signal. The use of high pass or band stop filters of good quality will prevent entry of the signal through the input. Other inputs such as power connections, speaker leads and other interconnection leads will have to be dealt with individually. Ferrite cores, RF chokes and capacitive bypassing will have to be used on some or all of these, as the need is found.

Physical separation is another method to achieve needed isolation, the vertical height separation is very important. It would be unwise to have the TV antenna and the fundamental transmitting antenna at the same height. More isolation is achieved in vertical separation than in horizontal.

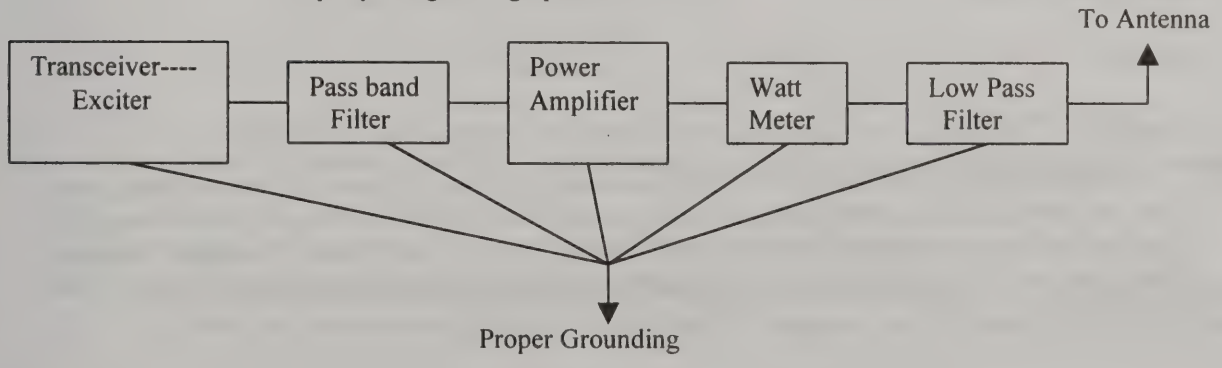
If a 90 degree difference of signal polarity between the fundamental and the TV can be arranged, a great amount of isolation will also be added, although a lot of VHF work is horizontal as is the TV signal, it will add to the isolation if you can operate this way.

3) How is it propagated?

A. Direct path

The direct path is very obvious, from the transmitting antenna to the receiving antenna. We all know that we are to use only the amount of power that is needed to maintain communications, so let's assume that the power needed is 1.5Kw .... just enough to make a good forward scatter QSO at 1500 mi. on 6 meters and we are in the fringe area of local TV, using an outside TV antenna . The absolute minimum amount of filtering to bring this into a workable situation would include:

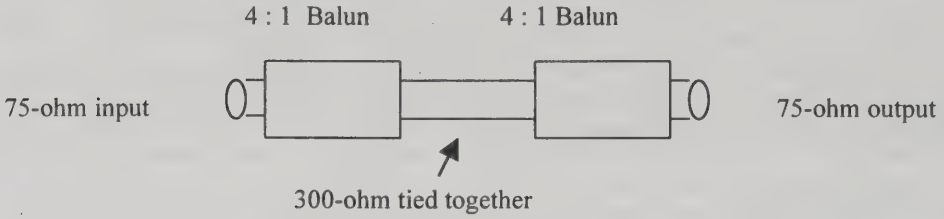
Good quality fundamental low level exciter
¼ Wave strip line filter in front of PA
Low pass filter at output of PA
Properly shielded and grounding of the PA
Good quality 100% shielded feedline
SWR at antenna adjusted to minimum
Good quality 100% shielded RF connecting leads
Properly designed high pass filter at TV



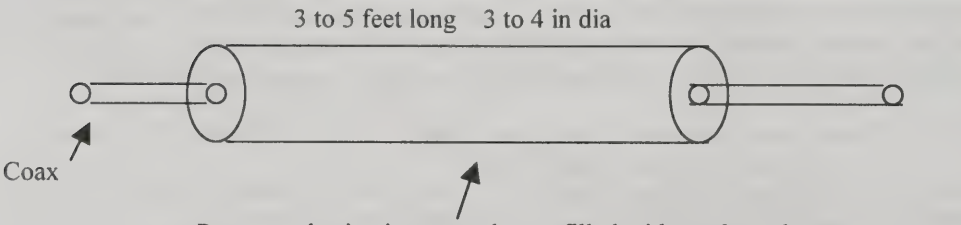
B. Common mode

Additional problems can arise if there is current flowing on the outside of the coax. Common mode problems can be minimized by using proper matching of the feedlines to the antenna and keeping the feedline out of strong RF fields. If you think you have common mode problems, filters can be placed into the system to eliminate it. A string of ferrite beads, a coating of lossey material surrounding the feedline or just burying the feedline in the ground for a good length will control current flowing on the outside of the coax. This common mode can also happen on the offended device incoming feedline. It to can be treated the same way. An additional common mode filter for 75 ohm TV receive feedline is made by connecting two 4:1 baluns back to back, on the 300 ohm side make the leads as short as possible. Although this will not pass AC/DC current that is used to power the inline mast mounted amplifiers that are in common use, it can be placed before or after as needed

75-ohm common mode filter for TV receive feedlines



Common Mode filter for either TX or RX coax,



4) Methods used to correct.

A. Filters

a. transmitter

Within the transmitter scheme there has to be enough rejection of harmonic energy to bring it to a level that will not interfere with electronic equipment. If the manufacturers did not provide enough, it is up to us to filter it out (or buy something that is better). With the use of properly designed lowpass filters, bandpass filters, shielding, physical separation and proper installation almost any situation can be resolved.

b. affected receiver

The affected device whether it be a TV, audio system or other entertainment device has to meet a minimum specification. A lot of what we buy, even name brand and expensive, does not have the ability to operate in a high level RF environment. It is up to us to find the specific area of deficiency that is allowing the problem to exist.

Each possible entrance path has to be evaluated, as to whether it is the path of interference. Start with the antenna line disconnected, if no interference, then only the antenna needs filtering, repairs or adjustment. If, with the antenna disconnected you still have the problem, then you have to look at any and all other connections to the specific device for their needed adjustment.

B. Transmit Antennas

Look for the antenna that is not designed to operate on harmonically related frequencies. If you have a problem with harmonic radiation, never use an antenna that is designed to work with multi-bands that are near problem frequency areas. Example, 50 and 222 if you have 4th harmonic problem with ch.11. Do not use a log periodic antenna or other interlaced mulit-band antenna if harmonic radiation is your problem. Mount the transmit antenna as high and as far away from normally used entertainment equipment as you can. Remember physical separation gives good isolation.

C. Receive Antennas

Be sure that there is a good quality 100% shielded feedline and the antenna is of sufficient gain for the area of reception involved. Be sure that it is pointed in the right direction. If needed move the receive antenna so that the fundamental transmitting antenna is in the rear quarter of it's pattern.

D. feedlines

If you are running over 100 watts and the transmitter feedline is 100 feet or longer the feed line should be no less than ½ inch hardline at 50 MHz and no smaller than 7/8 inch on 432. If you run at the legal limit a larger line is suggested. If you have a TVI / RFI problem there is no place for low grade coax in the system Use 100% shielded interconnection cables and hardline on the main feed.

On the receive line there should be nothing less than a good grade of RG-6, proper connectors (no screw on connectors) and proper weather proofing of all connectors.

5) Conclusion:

As most of you know the continual use of high power on 50 MHz will eventually lead to some type of TVI problem. The problem at times can be very difficult to cure. The location I live in has all the worst possible combinations you could add together. Listed below are the conditions my neighborhood sees TV with:

A. Near fringe reception area (60 miles and hilly terrain)
B. Channel 2 (WSB ABC)
C. Channel 11 (WXIA NBC)
D. No cable TV in the area

It has taken many hours of work to be able to operate 50 MHz within these conditions. To break down the problem, both the TV and the transmitter must be in almost perfect operating condition.

The first problem that was encountered was front-end overload of the TV. Ineffective front-end selectivity enhances our ability to overload the TV. It appears that the manufacturers of TVs are not

worried about the problem. None will provide the necessary protection when used in the presence of high power 6 meter operation.

The search for a high pass filter led to some QST articles from the fifties. A phone call to W2IDZ put us in the proper direction with a discussion of a design for a 300-ohm filter with good attenuation at 50 MHz and reasonable low losses through channel 13. He also discussed a 75-ohm filter of similar characteristic and construction technique. The designs that W2IDZ used met the operating criteria he and others used at the time. The mode and operating I am using are far removed from the ones he suggested. The articles in QST (July 1954) used ERP up to approximately 500 watts. The ERP expected for my operation is in the order of 200KW. An extra 25 dB would be needed.

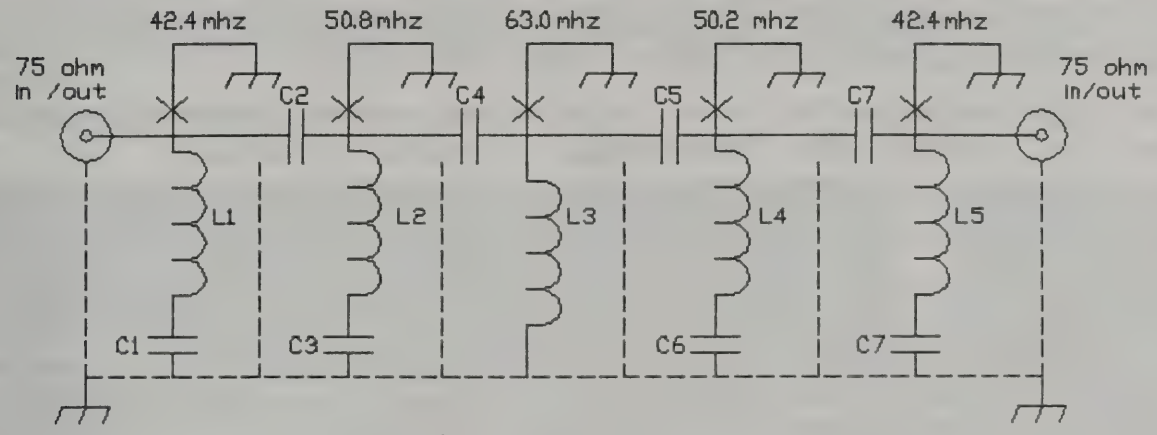
Many hours later with a sweep generator and spectrum analyzer, dozens of prototype filters on hand, a modified version of the W2IDZ type was developed that had > 80 dB of attenuation up to 40 MHz and > 65 dB through the lower portion of the 6 meter band and low loss throughout the VHF and well into the UHF TV band. A 75-ohm filter that proved to be sufficient to prevent front-end over load from high power 6 meter operation.

The final test, the highpass filter installed. To point the 6 meter antenna at the TV antenna and see if it would work. At full legal limit of power all front-end overload was gone. The physical separation is about 200 feet and the TV antenna and the 6 meter antenna are at about the same height. This condition is normal and can be repeated at any time. Demonstrations have been given to many hams that this configuration really works. A diagram and parts list is included to build this high pass filter.

6) Additional Related material

A. A High Power 2-Meter Filter, AF9Y, Proceedings of 24th Central States VHF Society 1990 Pg. 65
B. 6 Meter EME , WA4NJP, Proceedings of 22nd Central States VHF Society 1988 Pg.132
C. Lumped Element Filters for VHF and UHF, K0CQ, Proceedings of the 25th Central States VHF Society ,1991 Pg.1
D. High pass filter, W2IDZ, QST July 1954
E. Low pass filter, ARRL Handbook 1994 , page 31-37 fig 95
F. ¼ wavelength stub, ARRL Handbook 1994, page 31-45

All grounding shorts to be removed after resonating coils at their resonant frequency with a grid dip meter.



Parts List

L1,L5,L4	8.5 t	# 18 enam self support 5/16 ID
L2	10.5 T	# 18 enam self support 19/64 ID
L3	4 T	# 18 enam self support 5/16 ID
C1,C8		39 Pf Dipped Mica
C2,C7		47 Pf Dipped Mica
C3		22 Pf Dipped Mica
C4,C5,C6		30 Pf Dipped Mica

This high pass filter is patterened after a design that was developed by W2IDZ . The work was described in QST back in the fifties, the circuit is very near the same with some new ideas in place to make it work better.

If you are going to the trouble to make one of these, there are some rules you must follow:

1) Use a small die cast box (Bud CU-123)
2) Solder C1,C3,L3,C6 & C7 to a "U" shaped ground plane in the bottom of box made from brass, held in place by the coax connectors at each end of the box.
3) Install shields between coils to reduce mutual coupling , (.625 X .750)
4) Use short large size wire for grounding shorts and just clip lose at coil after resonating each at the right frequency.
5) C2,C4,C5 & C7 should be in a straight line between the two coax connectors.
6) Hot end of L1,L2,L4 & L5 are supported by small Teflon standoff insulators.

Six Meter Yagi for Contesting and Expeditions

by Dick Hanson, K5AND

The following article will describe a very effective antenna which is easy to transport and takes minimal time to assemble once you've gotten to where you're going.

But first, you might want to ask "Why such a large antenna, why not something smaller like a two element quad or maybe a little 3 element yagi?" Here's the long answer...

If you're going on a expedition, you're spending time and money. Here's why you get more bang for your buck with a larger antenna.

- The band will open earlier and stay in longer...while it may not appear to open at all with a small antenna.
- If you will be near the water and at some reasonable elevation above it, you can take better advantage of "ground gain" (3-6db) with the larger antenna. It's really hard to believe how much difference this can make on F2 and multi-hop E skip.
- The sharper patterns afforded by the larger antennas really help with noise discrimination, which is often a problem on these trips.
- On some of the islands we've been, there were local stations on, but using much more modest equipment for antennas and power. Many times, they are not heard by the DX, nor can they hear the stations we're working.
- Also, keep in mind that many of the DX stations are not running high power or large antennas...so the extra gain in this antenna really helps pull them through.

Design

Many of you know by now that I'm not an engineer, so you may wonder about some of my choices for construction etc. Hey, I'll admit that I learn from others...I have had the privilege of having been on a fair number of contesting efforts as well as dxpeditions…so I've picked up a few thoughts along the way, especially from people like Jimmy, W6JKV and Mike, K6MYC.

This yagi was designed using K6STI YO 6.5 software. The specs, while pretty fair, still represent a compromise depending on your design goals. For me, it needed to have good forward gain, good front-to-back, fit into a 5 1/2 foot carton and be very simple and fast to put together. I also wanted a matching system that was as fool-proof and as weather-resistant as possible (because it RAINS on mountain tops and on Caribbean islands).

Specifications

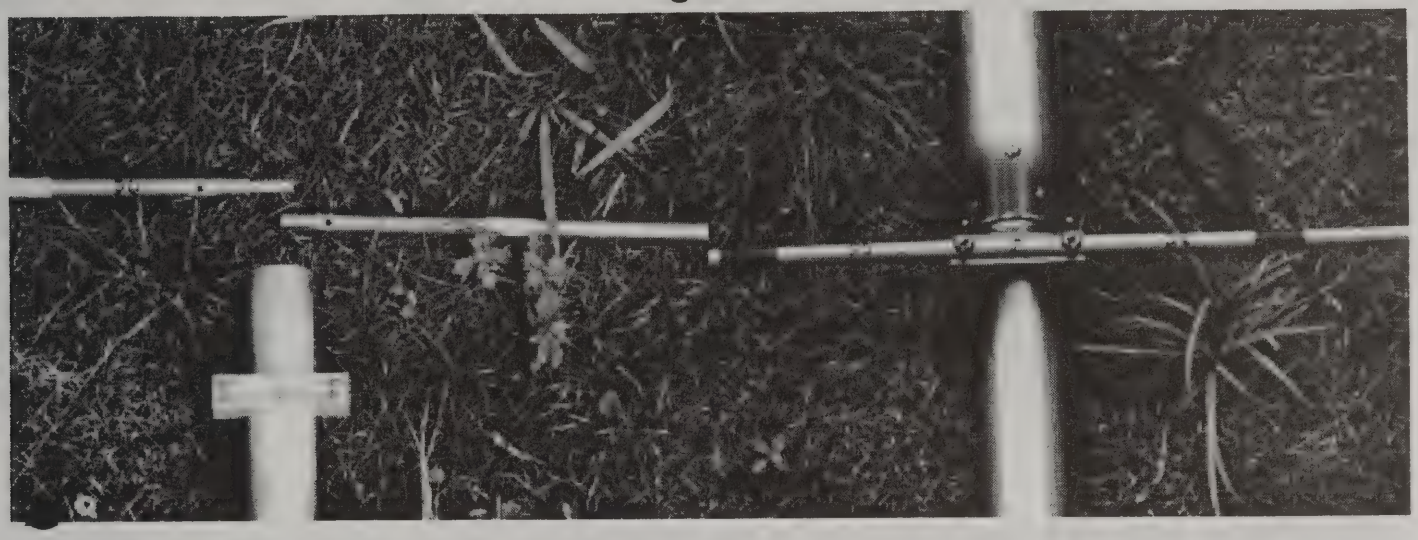
Gain.....11.5dbd
F-B.....28db
Boom length.....37ft
Power handling.....5kw
Matching.....hairpin with 50 ohm 1:1 current balun
Weight.....20 lbs

Construction

Once the antenna was modeled on YO, it was time to start figuring out the materials list etc. I started with a decision to use 0.375" elements. The next step was to design the boom. Please refer to fig.1 to see the construction technique and sizes of tubing. All of the tubing came from Texas Towers.

One of the main things contributing to the simplicity and ease of assembly is the use of wing nuts. They are used everywhere...except at the boom to mast clamps. Another item that streamlined construction and assembly is the element to boom clamps. As you can see in fig. 2, the clamps are machined from aluminum block. Because the boom has several different diameters, the clamps have appropriately sized holes machined to fit the boom where that element belongs. All of the clamps have a 0.375" groove machined in the top to accommodate the elements.

Figure 2



The elements are split in the center to allow them to fit into the 5' carton. They are secured to the clamps with captive 6/32" stainless studs which have been threaded & epoxied into the clamp. I also inserted a 1.75" piece of 1/4" aluminum rod into the center point of each element to act as a splice and give more rigidity to the element for clamping. Two 6/32 wing-nuts secure the element to the clamp. Each clamp also has a captive 10/32" stud protruding through the boom and is fastened with a 10/32 wing-nut.

Driven Element and Matching

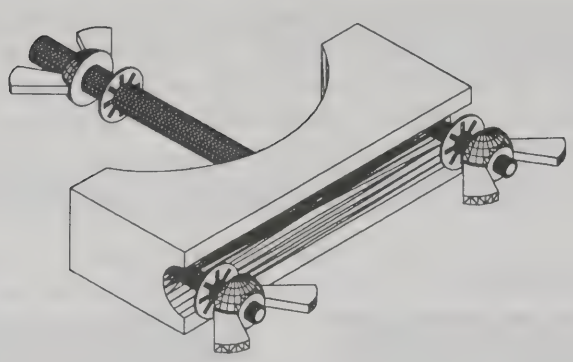
The driven element boom to element clamp is machined from black Delrin. As you can see from fig. 3, it too has several captive studs for mounting the driven element halves as well as fastening to the boom. Wing-nuts are again used here to secure everything.

The 50 ohm 1:1 balun and hairpin match apparently are a little off the beaten path at 50 mhz. Or at least I have not seen them in combination before in the literature for this band. They really work well together...and there is nothing to tune or get out of adjustment...so it's really hard to screw things up.

The hairpin was made from 1/8" copper tubing; I then sprayed it with lacquer to delay the oxidizing process.

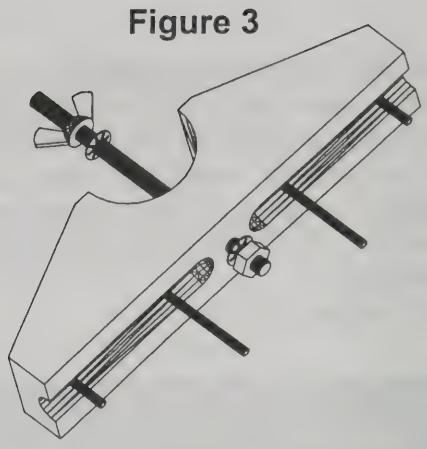
The balun can take several directions: you can use RG-142 teflon coax, or you can use RG-393 for super power. I made several baluns with each type of coax with the right sized Amidon beads(see the appendix for part numbers and mix, and see fig. 4 for the balun details). I enclosed each balun in shrink tubing which not only weather-proofs but also makes them more rigid.

Figure 2a

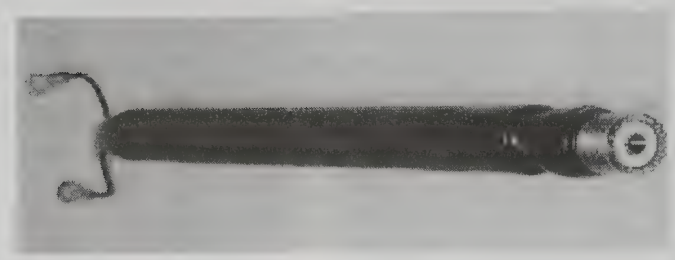


Boom to Element Clamp

Figure 3



Driven Element to Boom Clamp



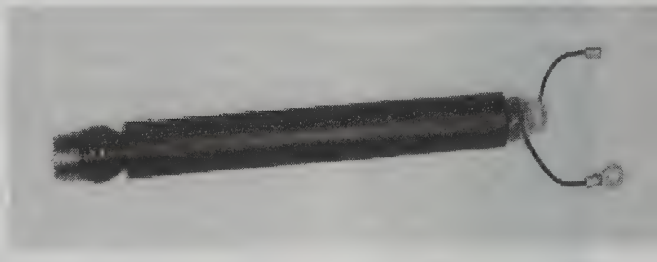


Figure 4

Tuning

Many thanks go to Bob Lear, K4SZ, for all his efforts on my behalf helping tune this thing on my back porch during the middle of August. We played with the hairpin length and the driven element length to get the swr curve where we wanted it (centered on 50.110). The swr measures 1.2 to 1 at 50.0 and 1.2 to 1 again at 50.250, so that's not too bad. The height above ground was about 20 feet, so we figured things wouldn't change much when the antenna was on a pole or tower in some remote location.

Sure enough, the tinkering on my porch paid off! No change when erected at a height of 24' (plus 150' over the water) at J79AND in November of '99.

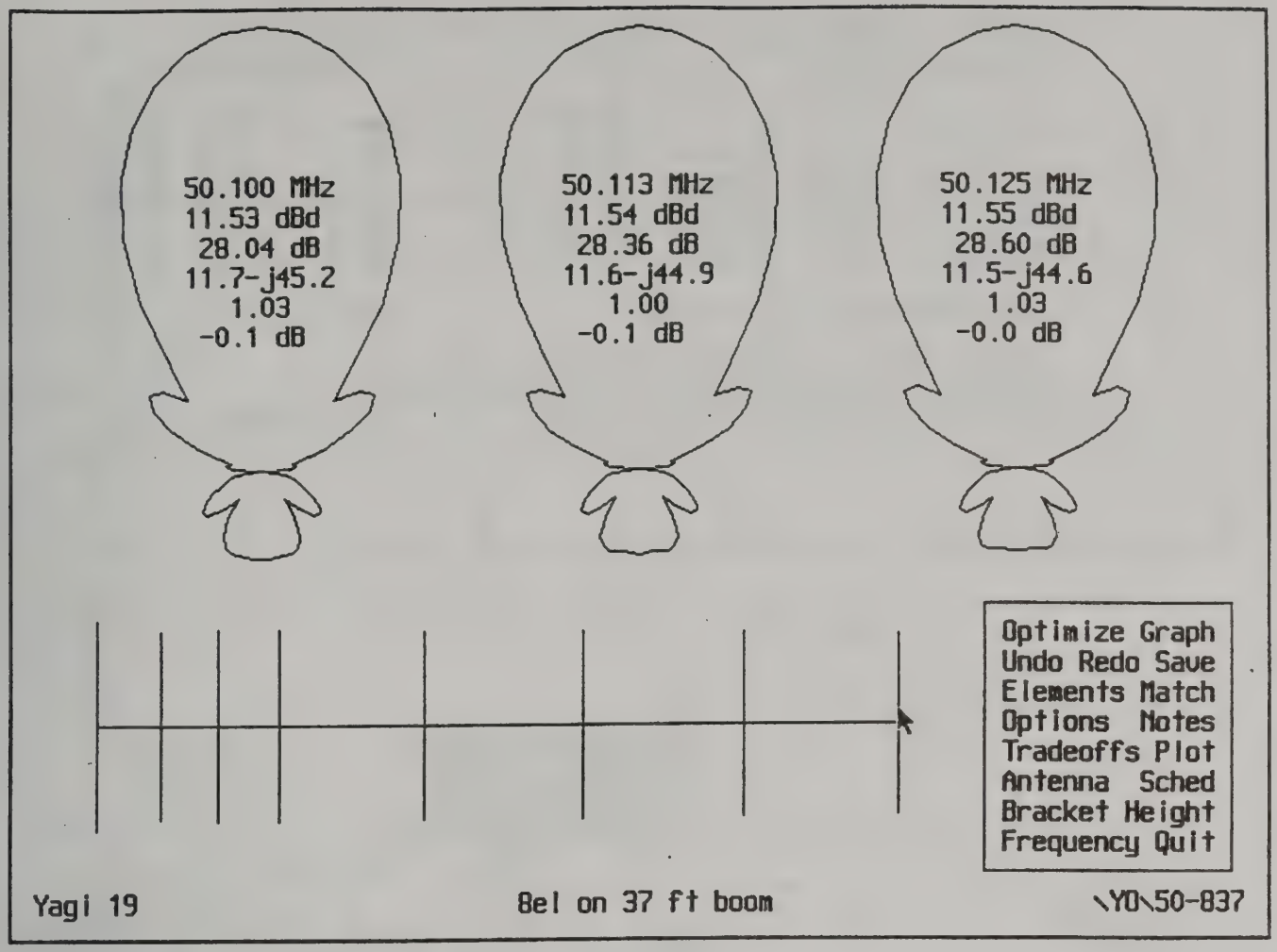
Summary

If you need an antenna for contesting or dxpeditionss...I'd recommend one similar to this one. If you were going to use it at your home station, I'd change from wing-nuts to stainless aircraft nuts with lock-washers. It would also make sense to have the elements be one piece rather than two since portability would no longer be an issue.

By the way, in case you're wondering if the antenna will survive ice and wind...I don't know. I do know that the boom is very stout with the Dacron boom guys in place and I would not expect any problems. If you want to go to 1/2" elements for icing concerns, that would be very easy to do, and If someone needs them modeled, e-mail me for dimensions.

Here are some additional notes on the antenna. Most are files directly imported from the YO 6.5 program.

The Amidon cores are type 6873-43 for use with RG-393 coax; use 5621-43 for the RG-142BU. I used six each on my baluns, terminations can be Teflon 50239 or Type "N". I also used "hoods" to minimize impedance "bumps". If anyone would like more detailed info or has questions, please contact me at home 770-844-7002; home fax is 770-889-8297; work phone is 770-888-7333; work fax is 770-888-7343; e-mail is k5and@ga.prestige.net.



Untapered Equivalents

		Position	Fixed Length
Ref	→	0.000	58.051"
DE		35.500	54.250
Dir	1	66.750	53.426
Dir	2	101.000	52.926
Dir	3	179.500	52.551
Dir	4	268.625	52.113
Dir	5	357.500	51.426
Dir	6	443.500	50.176
Boom		37' 0"	1.88λ

Taper Schedule

		→ 1.189	0.375"
Ref		1.250	57.125
DE		1.250	53.323
Dir	1	1.250	52.500
Dir	2	1.250	52.000
Dir	3	1.250	51.625
Dir	4	1.250	51.187
Dir	5	1.250	50.500
Dir	6	1.250	49.250

Hairpin match: 0.125 rod; 1.5" spacing; 3.125" length; 54.25" DE length; 1" leads; 0.3pf shunt; Z=50 ohm. Current balun is 5ea 1.125" ferrite beads, 43 mix on RG-142BU teflon coax.

8el on 37 ft boom
50.100 50.113 50.125 MHz
8 elements, inches

	1.1886	0.3750	
0.0000	1.2500	57.1250	58.375
35.5000			54.25
66.7500	1.2500	52.5000	53.75
101.0000	1.2500	52.0000	53.25
179.5000	1.2500	51.6250	52.875
268.6250	1.2500	51.1870	52.4375
357.5000	1.2500	50.5000	51.75
443.5000	1.2500	49.2500	50.5

This design uses .375" elements.

Hairpin match: 0.125 rod; 1.5" spacing; 3.125" length; 54.25" DE length; 1" leads; 0.3pf shunt; Z=50 ohm. Current balun is 5ea 1.125" ferrite beads, 43 mix on RG-142BU teflon coax.

9/1/99

Untapered Equivalents

		Position	Fixed Length
Ref	→	0.000	58.051"
DE		35.500	53.426
Dir	1	66.750	53.426
Dir	2	101.000	52.926
Dir	3	179.500	52.551
Dir	4	268.625	52.113
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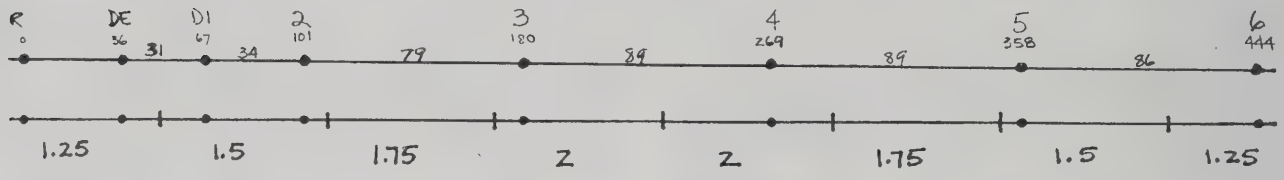
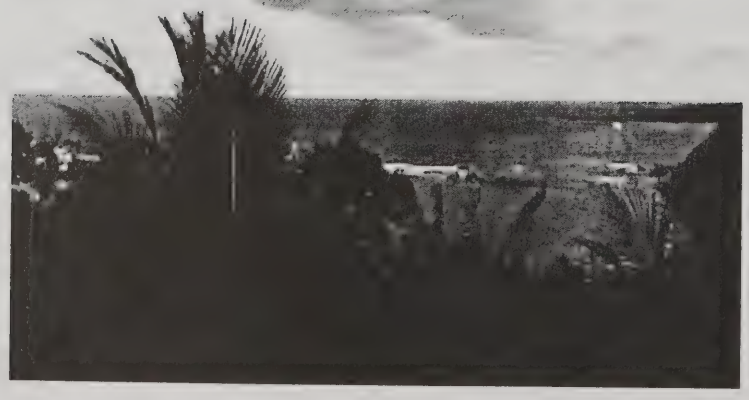
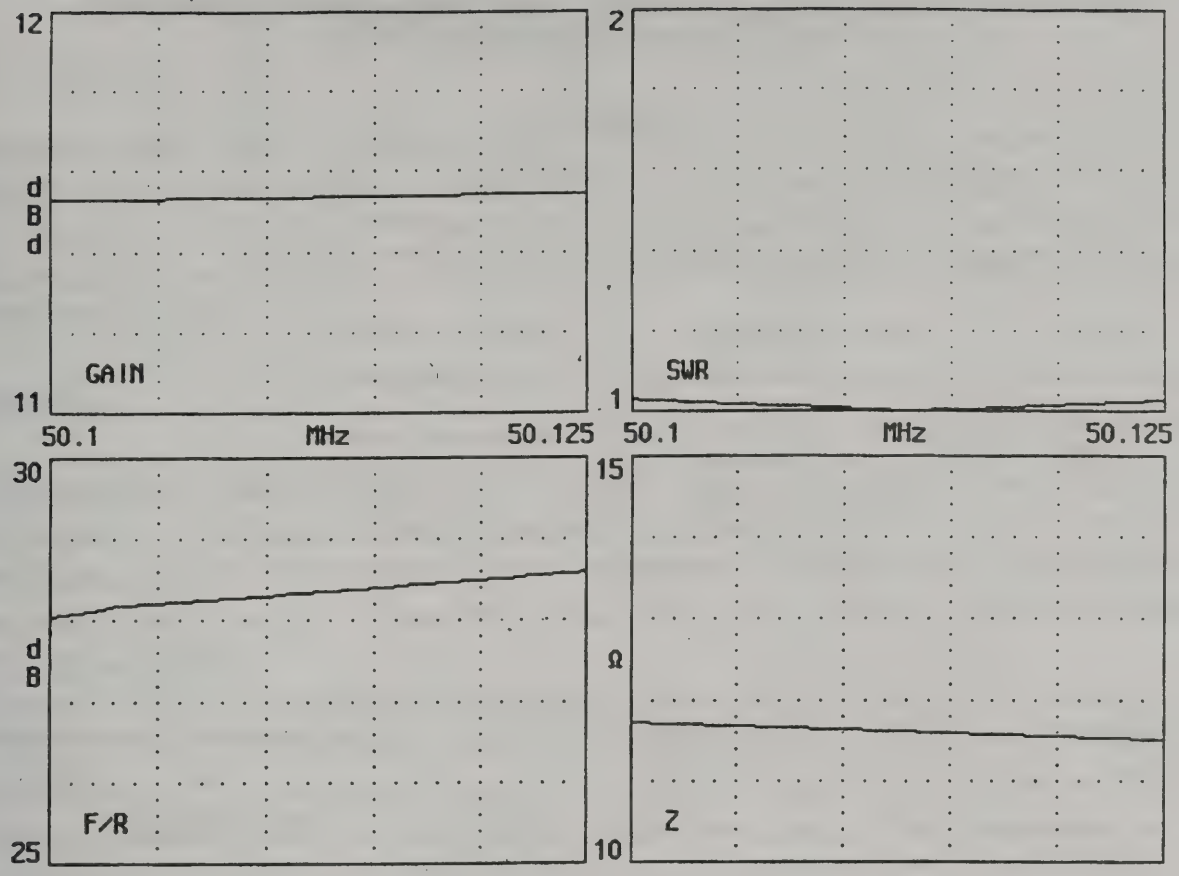
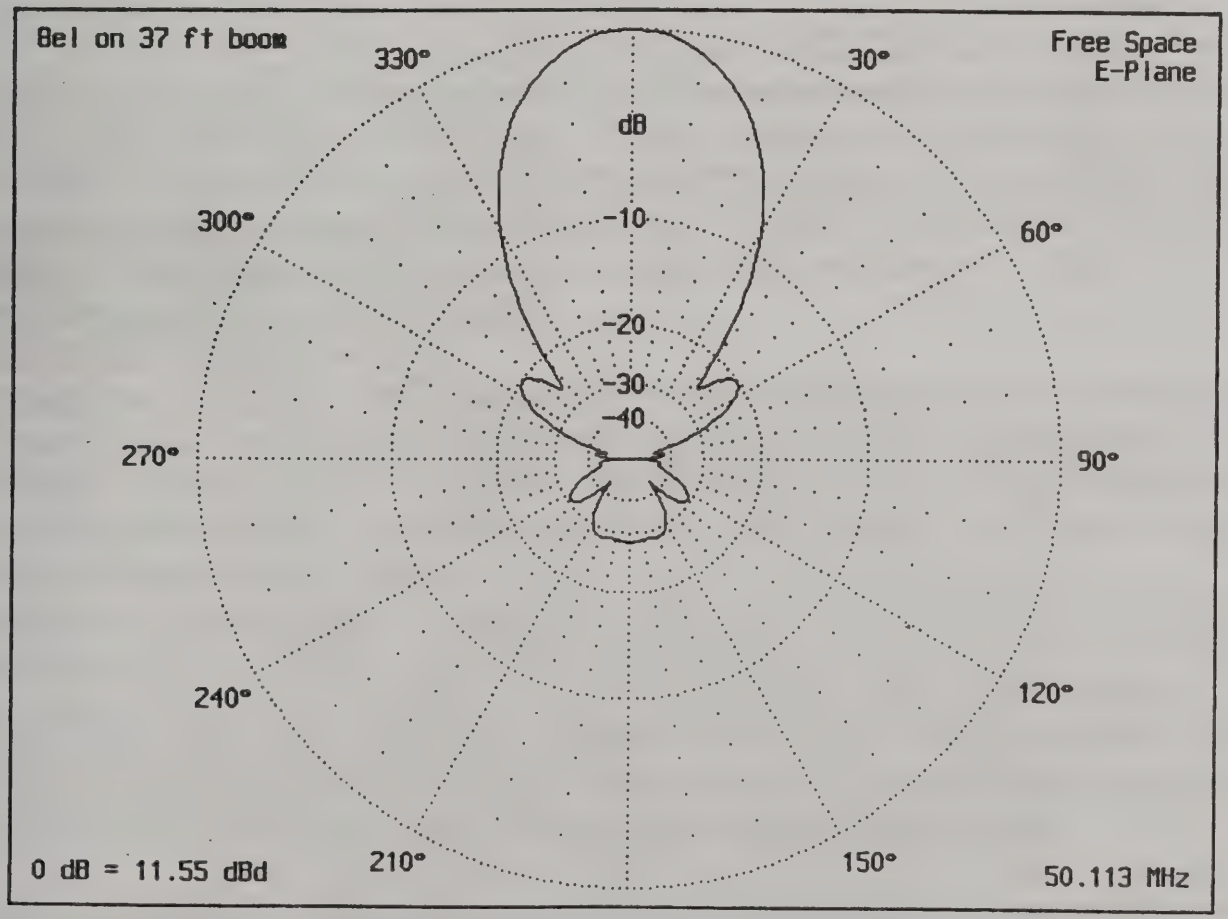
Boom		37' 0"	1.88λ



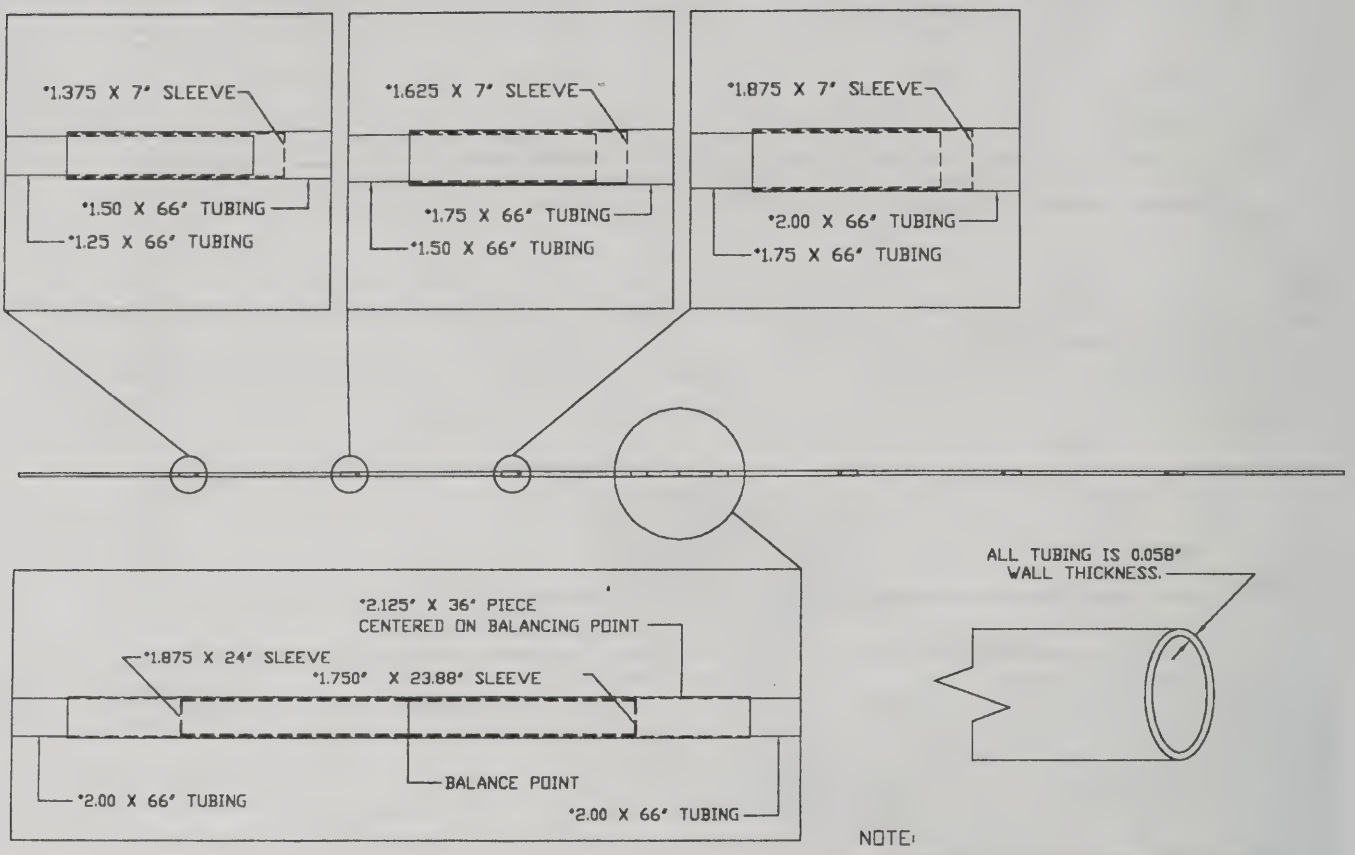



12
d
B
d
GAIN
11
50.1
MHz
50.125
2
SWR
1
50.1
MHz
50.125
30
d
B
F/R
25
15
Ω
Z
10


8el on 37 ft boom
Free Space
E-Plane
330°
30°
dB
-10
-20
-30
-40
300°
60°
270°
90°
240°
120°
210°
150°
0 dB = 11.55 dBd
50.113 MHz

Boom Construction

Figure 1



NOTE:

EACH BOOM SECTION IS 66' LONG, WHICH ALLOWS A 6' TELESCOPE INTO THE NEXT LARGER SECTION. AT THE INSERTION END OF EACH TELESCOPED PIECE, THERE IS THE NEXT LARGER SIZE OF TUBING, 7' LONG, ACTING AS A 'SLEEVE'. AT THE CENTER OF THE 2' SECTIONS, THE 'SLEEVE' IS 24' LONG, MADE UP OF 1.875' & 1.750' PIECES. A 2.125' PIECE 36' LONG IS CENTERED ON THE BALANCE POINT. THE BOOM IS SYMMETRICAL, THE DIMENSIONS SHOWN APPLY TO THE OPPOSITE SIDE AS WELL. ALL TUBING IS 0.058' WALL THICKNESS.

Rotating Mast for Expeditions & Mountain-topping

by Dick Hanson, K5AND

This article deals with a portable, easy to assemble, 24' rotating mast with the rotator bottom-mounted. It is suitable for small tri-band antennas or fairly large six-meter antennas. It needed to fit into a 5 °' carton for shipping airfreight, yet be rugged enough to withstand a lot of wind torque. The resulting system is fairly light, strong and very easy to erect in minimal time.

Construction

All the aluminum was purchased from Texas Towers. I decided to use 2" OD tubing cut into 5' sections. Each joint is reinforced with an internal sleeve of 1.875" tubing and an external sleeve of 2.125" tubing. Four 2 °" stainless bolts with ˇ X 20 stainless wing nuts secure each joint. See fig. 1. Everything has been color-coded to eliminate guesswork in some remote location.
The bottom of the first section has been built up over a 1 foot length by telescoping pieces of 1.875, 1.75 and 1.625 tubing inside. This prevents crushing the mast in the rotator.
Approximately 17' up the mast, there is a ˇ" wall by °" high bushing screwed to the mast; this is to provide support for the rotating guy ring which rests on the bushing.
The guy ring is a ˇ" thick by 5" diameter aluminum disk, with 3/8" holes drilled for either 3 or 4 guys. See fig. 2.

At approximately the 20' point, the boom to mast plate is attached. See fig. 3. The top 4' of mast is for the overhead boom guy, and is made to telescope into the top of the top 2" mast section. The bottom as well as the top of the 4' top boom guy mast is made thicker by telescoping 1.875, 1.75 and 1.625 section inside. This provides almost a ˇ" wall to clamp the boom to mast plate without danger of crushing the mast. I use a 2" muffler clamp at the top to secure the boom guy turnbuckles.

The rotator mounting plate is 12" square by ˇ" thick aluminum plate. I machined four 1" aluminum spacers to mount the rotator to the plate. In my case, I happened to have an extra Ham 4 rotator, so this is what was used (see figure 4). I attached connector pigtails to both the rotator and the control box so that my 100' "extension cord" simply plugs in at both ends. Really simple, really fast.
I use the heavy Dacron rope for mast guys, and I always carry at least 4 army surplus guy stakes that aren't too heavy. I also drilled four 3/8" holes in the corners of the aluminum plate to accommodate some very large (3/8 by 12") nails I found at the hardware store. Pushing these babies into the ground through the rotator mounting plate does an excellent job of keeping the base from twisting in the wind etc. Experience has shown that two people can easily "walk" this mast, with antenna mounted, into position.

If you have questions, please phone or e-mail me. k5and@ga.prestige.net 770-844-7002

Figure 1

Figure 2

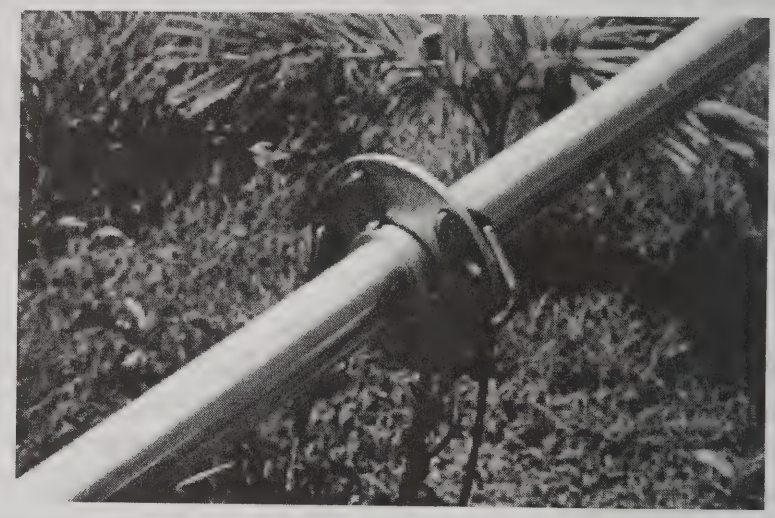


Figure 3

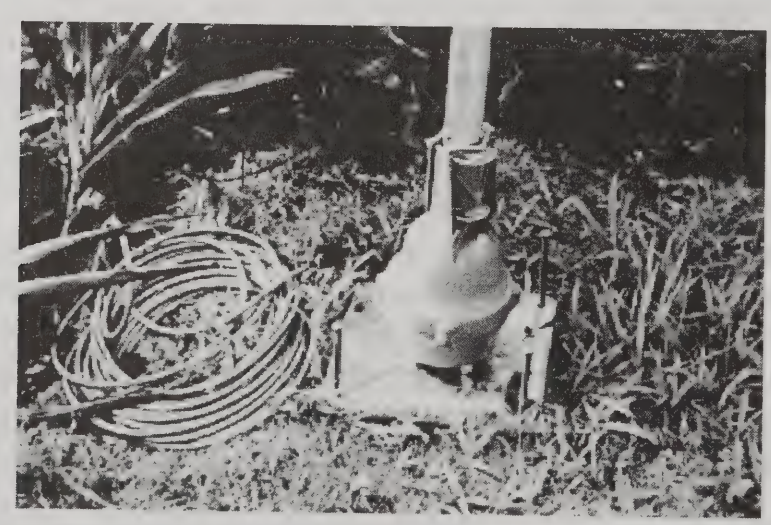
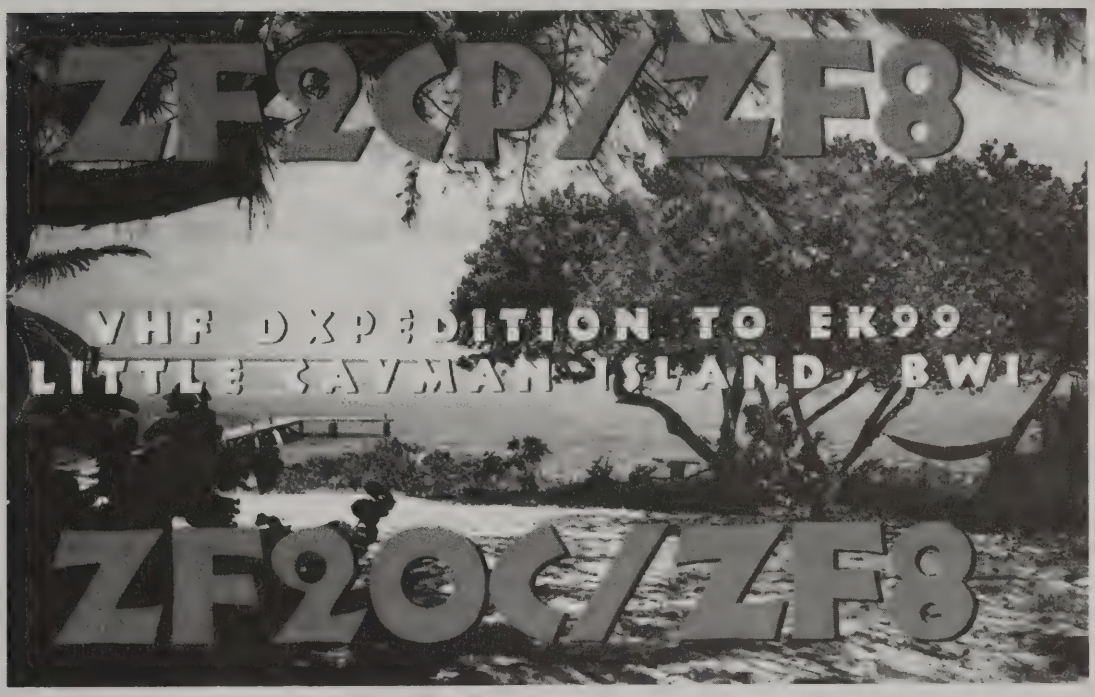


Figure 4

VHF DXPEDITION - YOU CAN DO IT

CHRISTOPHER M. PATTERSON
W3CMP EX WA3HMK
WA3HMK/VP5,ZF2CP
W3CMP@AOL.COM



How many times while listening for a Caribbean DX station or trying to break through a pileup for a new one on 6 or 2 meters have you thought how much fun it would be to be the DX instead of the chaser? Chances are you have at least once. You also probably let the urge pass as soon as you thought about the amount of work involved.

A fair amount of planning and work is required to properly execute any Dxpedition, and a VHF Dxpedition in particular. However, the availability of off-the-shelf high performance antennas, amplifiers, and compact HF-VHF transceivers in the past few years has made portable VHF operation possible for almost anyone. Moreover, the satisfaction and pleasure of a successful trip will far outweigh your effort.

Before you take off on your trip, there a number of radio and nonradio matters to consider. Some require a bit of thought; most are common sense. Many questions can be answered by others who have done it before. A few, and perhaps the most important, can only be learned by doing it yourself.

I. GENERAL CONSIDERATIONS

Well in advance of any trip outside the United States, find out what form of identification is required for entry into the country you intend to visit. Many countries only require a photo ID e.g., driver's license. Some require a passport. Passports take several weeks to obtain, so don't wait until the last minute to get one.

Make sure your vaccinations are updated. You might want to consider Hepatitis, Typhus, and certainly Tetanus. Get certificates showing they are current.

Check on your health insurance coverage. Be sure you bring a current health insurance card with you.

If you take prescription medicine, get a current prescription card to take along. Take some extra medicine to cover any unforeseen delays.

Find out what the local currency is. If U.S. dollars aren't used, get local currency before you go. Exchange rates are usually better here. Traveler's checks are a good idea. Clear your wallet or purse of all unnecessary credit cards. If your cards are stolen or lost, you've got a major headache.

Decide who is going along. Setting up and operating a serious portable VHF station is work, and a companion/spare operator is always welcome. Compatibility is very important. You do want to be friends at the end of the trip.

How long are you going to stay? Think in terms of a week minimum; two weeks is better.

Don't neglect to insure your radios and other personal property. Trips are expensive enough without factoring in radio replacement costs. If your equipment is lost or damaged, you want to be sure it gets replaced without any hassle.

Visit your local travel agent, bookstore and AAA. Get some travel guides on your prospective locations. Look on the Internet. Scuba diving, sailing, and sport fishing bulletin boards are great sources of information about various locations.

Apply for your foreign license several months in advance of your intended departure date. You will have enough things to do without having to worry about that. The ARRL can provide information and application forms. If you can enlist any local hams to help you, do so. Not only can they assist you in the licensing process, they often can ease your passage through customs. Don't forget to treat your host to dinner or bring a small gift.

Prepare an equipment list or manifest to take with you. (Appendix A1) The manifest should contain each piece of equipment, its manufacturer, and if applicable, serial number. Some countries require the list to accompany the license application. One copy should contain the value of each piece of equipment; the other should not. Some countries require the posting of a cash bond to ensure the equipment leaves with you.

Make check lists for everything. (Appendix A2-4) Check and recheck them. Give yourself deadlines for having your flight and accommodation reservations, equipment checked and packed, etc. Try to have everything ready to go a week ahead of your departure date. Remember, if you forget something you can only blame yourself, and chances are you'll be more than a little upset.

How you get your equipment there (and back) is important. Most people cannot afford to

donate equipment to the airlines. Cardboard boxes are cheap and disposable. (Figure 1) They can be made to almost any size. The only down side is that they become mush when they get wet and probably won't last more than one trip. Double or triple box your stuff and use lots of foam. PVC tubes are another option for antennas and masts. They are waterproof, and can be made any length. They too can be damaged.

Cardboard boxes used to take equipment to Little Cayman Island.

Figure 1

If you get serious about the expeditions, you may want to invest in some type of permanent cases for your equipment. Surplus military plastic cases are waterproof, rugged, and lockable. Pelican® cases are very good. They are rugged and waterproof. Custom cases are another option. They can be made with heavy duty wheels and handles so you don't have to break your back carrying your amplifier through the airport. Several manufacturers are listed on the Internet. My

rule of thumb is that anything you pack equipment in should be able to protect it in a four foot fall. Airlines do destroy baggage on a regular basis.

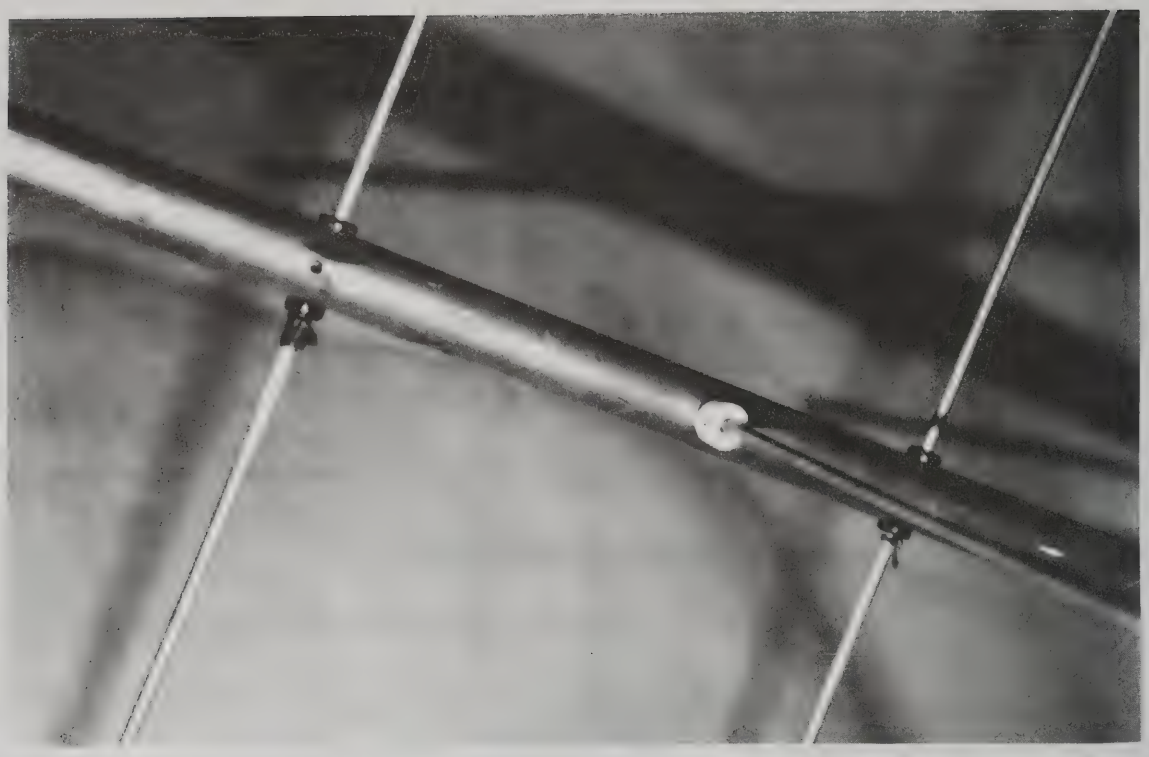
Check with your airline(s) and travel agent about excess baggage charges and restrictions on baggage. Common restrictions are usually two carry on bags and two check bags of 70 lbs. Try to get an overweight waiver. Excess baggage is very expensive.

Carry on your most valuable equipment - transceiver, power supply, dipole antennas, and if you have a strong back and a weak mind, linear amplifier.

Consider freight forwarding. K5AND has utilized Amerijet in Atlanta. The company has offices in several cities, and according to Dick, gives good service. You can ship your equipment ahead, and don't have to carry it through every airport.

Make sure all your equipment operates properly before you go. Assemble the entire station - antennas too - and operate them exactly as you intend to on your trip, i.e., hard. A VHF contest is a good test. There is nothing more frustrating than going to a remote location and finding out that your transceiver eats preamps or antenna parts are missing. Remember, there are no Radio Shacks in most of these places!

When you disassemble the station to pack it, mark everything for easy reassembly. Magic marker or colored electrical tape works on boom sections and antenna elements. Match cable ends. Insulated through-the-boom elements can be installed and reinstalled by using temporary retainers on one side. Nylon cable ties, shaft collars, or electrical tape are all useable. (Figure 2)



Several methods to attach through-the-boom insulated elements for temporary use.

Figure 2

II. SPECIFIC CONSIDERATIONS

WHERE DO YOU WANT TO GO - WHAT ISLAND OR COUNTRY?

Where you want to go in large part is determined by available accommodations, where you want to work, when you want to go, accessibility, rareness, and nonradio activities.

ACCOMMODATIONS - There are three categories of accommodations. They are resort, cottage (villa), or true Dxpedition. Resorts can be very attractive. They can offer meals, organized activities, e.g., golf, swimming pools and other amenities that cottages do not. They may also have maintenance personnel who can help you with set up and who can tell you where to obtain anything you need locally. Larger resorts may have combined airfare - accommodation packages which can be quite attractive. Many smaller resorts have hosted Hams before, and have set aside certain areas for Ham rental. The negatives are cost, the possibility of numerous TVI problems, and physical

limitations on the antennas you can erect. Try to get pictures of available accommodations so you can determine ahead of time where your antennas can go.

Cottages or villas may offer more flexibility for locating antennas, and to some extent more privacy. You may have to supply bedding, and they may not be air conditioned. You may also have to find groceries and prepare your own meals. Food is generally very expensive, and the selection is not what you normally see in the states. Some cottage owners cater to Hams; they are better equipped and can offer HF equipment and antennas, towers, and in some cases, VHF equipment. Several advertise in QST, and others host HF contest groups. P49, C6, VP2E, ZF2/ZF8, V2, (Figure 3) and VP5 (Figure 4) are locations which have cottages which cater to Hams.

ZF8AA Cottage, Little Cayman Island

Figure 3

"Hamlet" at Providencalies, Turks & Caicos

Figure 4

The true Dxpedition is for those who want to bring everything from fuel to generators to tents. This operation is beyond the scope of most individuals. If you feel the urge to try this, call Jimmy Treybig, W6JKV/5 or contact some of the large HF expedition groups.

Wherever you go, you must be aware of the available line voltage, and type of power connectors. Obtain the proper adapters and plugs before you go.

You must also think about where your intended accommodations are located. Select a location that favors the paths you want to work. If you want to work to the north towards the U.S., or northeast towards Europe, you have to be on the north side of an island if there are any mountains. Try to find a place near the water with a good radio horizon. Get the antenna as high as possible. Try to avoid power lines, and other sources of noise and junk, e.g., generators, cable TV, etc.

Necessities at any location include lots of bottled water, soft drinks or beer, bug repellant and suntan lotion. (Appendix A5) You will be surprised at the amount of fluids you need to consume, and how easily you sunburn. The number and voraciousness of native mosquitos is beyond description.

Sources of accommodation information include QST, CQ, Dick Hanson, K5AND, Jim Treybig, W6JKV/5, Mike Stahl, K6MYC, the Internet, and the real estate sections of large city newspapers.

SAFETY - Safety can be a real concern, especially if you are taking your wife, friends or family. Jamaica, Haiti and Nicaragua, for example, are ideal Dxpedition locations, but at the present, the only realistic accommodation consideration is some type of all inclusive, secure resort or villa. Check with your travel agent, and look for travel advisories on the Internet.

TRANSPORTATION - Getting to your destination and getting the equipment there in operating condition are often the most challenging aspects of your trip. Although many islands have direct flights from U.S. cities, others entail stopovers. Stopovers may require overnight stays. Each change of planes involves unloading and reloading your equipment, and increases the chances of loss or damage. Smaller airlines change schedules without warning and may not be able to carry large packages. Try to take direct flights whenever possible.

Think about how to get around when you are there. Consider renting a car; for a smaller island, a moped or bike. Although expensive, the flexibility and convenience they can provide is well worth the cost. Local jitneys may offer an alternative. Be aware of what transportation is available before you go.

WHERE DO YOU WANT TO WORK - More important than your accommodations is where you want to work. Your operating goals will affect where you go, when you go, the equipment you take, the band(s) you operate, and the accommodations you choose.

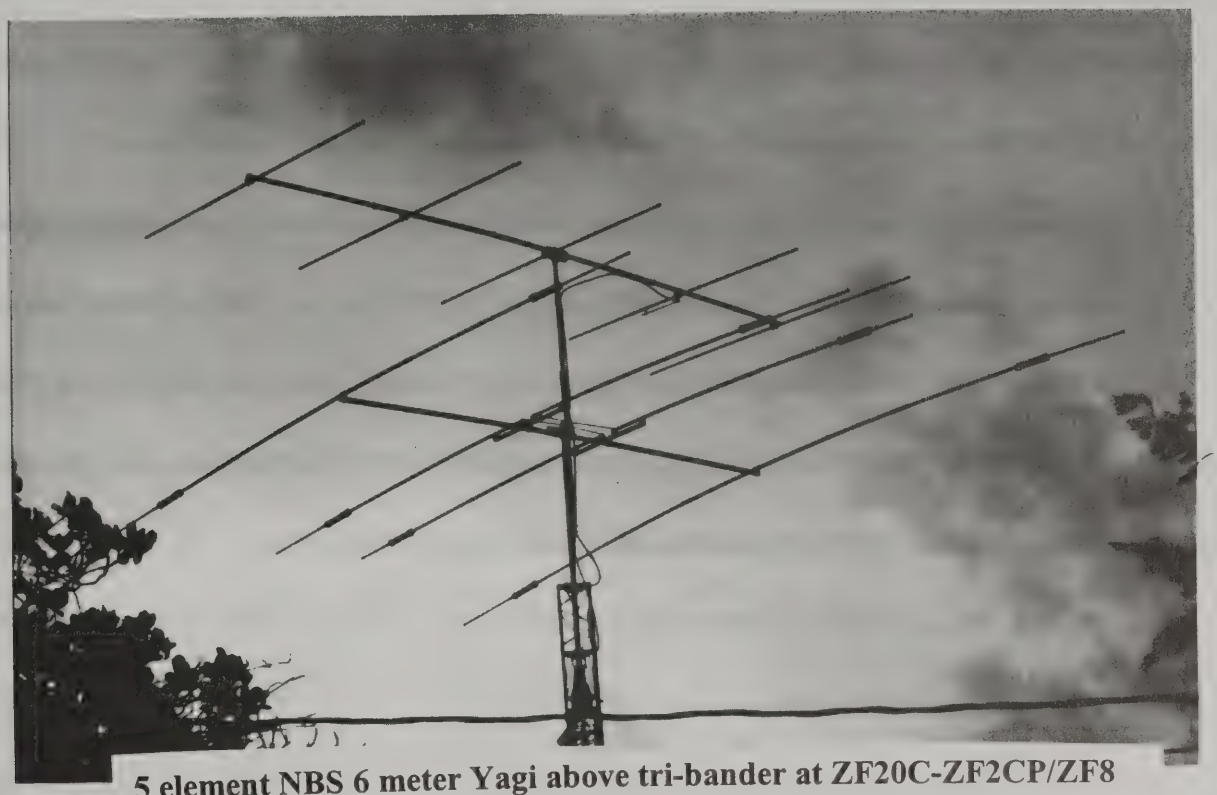
Firstly, think about what bands and what modes you want to operate. For a casual DXexpedition, an HF-6 meter transceiver and a small antenna, e.g. 2 or 3 element quad or 3 element yagi (Appendix A-7), may suffice. You probably won't work any marginal stuff, and may come home frustrated. If you want to increase your chance of success, concentrate on exactly what you want to accomplish, and bring as much antenna and power can as you can.

6 METERS - offers the best opportunity for contacts. Summer Sporadic E season runs from mid May to mid-July; it peaks about the end of June. From the Caribbean, contacts with Europe, Africa and the Pacific, via multiple hop E are possible. Fall/spring F2 and TE propagation offer an opportunity for world wide DX. Transequitorial propagation across the equator peaks in March and September; F2 peaks in the fall and winter.

Meteor scatter and EME are also viable modes. They are not generally the focus of 6 meter dxpeditions. However, if your location is within meteor scatter range of the U.S. (or other country) meteor scatter can provide a good opportunity for contacts. EME may allow you to work a number of stations with the aid of ground gain.

Any serious 6 meter operation needs a kilowatt amplifier and at least a 10 - 11 db antenna (25-40' boom). Amplifier possibilities include the Tokyo Hi Power HL-1K6 (not available in the U.S.), a modified Commander II 2 meter amplifier, ARCOS (no longer produced) or homebrew. Another option is Command Technologies VHF-1200, which is a little bulkier. K5AND and W6JKV use 40' portable 12 db design yagis; in the past I've used 4 and 5 element NBS yagis.

(Figure 5) I now use a 23' modified A50-6 that gives 10+ dbd. The M² 6 M7 JHV antenna is a good candidate for portable use.



5 element NBS 6 meter Yagi above tri-bander at ZF20C-ZF2CP/ZF8

Figure 5

Suitable radios for 6 meters include the FT-847, DX 70TH, IC-706 MKII and TS-690. Single band radios like the TS-60, FT-650, etc. may also be okay but require a separate HF radio for liaison. Narrow SSB and CW filters, DSP, a good impulse noise blanker, and the ability to tune below 50Mhz (to monitor propagation indicators) are requisite features. If you can afford it, or have a good friend, take a second rig to serve as a back up. It will allow you to monitor 28.885 Mhz or 14.345 Mhz while you are on 6.

A memory keyer is also a necessity. You will want to set up a beacon. If you can't operate CW, either learn or bring someone who can. Propagation is often too weak for SSB. Wire dipoles for 6, 10 and 20 meters are also important. A 6 meter dipole gets you going quickly and provides

an antenna for your beacon after you get the big antenna up. The HF dipoles will allow you to set up skeds, monitor the propagation, etc.

To power everything you need a switching power supply with 110/220 volt input. A linear supply is too heavy. Make sure the power supply doesn't generate RF hash.

You will also need a supporting mast or tower for your antennas. I use an 8 foot tower which I got several years ago. (Figure 6) W4HP cut the legs into 4 foot pieces which are bracketed together. It weighs 33 lbs. and provides a good base for a large 6 meter or 2 meter EME array. K5AND has hombrewed a 15-30 foot mast which breaks into 5 foot sections. He puts the rotor at the bottom to decrease the top weight and to make it easier to erect.

Portable tower at VP5/WA3HMK. WA3HMK and helper Paul.

Figure 6

Commercial products which will support portable antennas include the M² "Fastman Mast", a 20 foot telescoping mast that allows the rotor to be mounted at the top or bottom. The Glen Martin Engineering tower may be an option. For HF liaison antennas, Bill Kelsey, N8ET, of Kanga US, sells a knock down fiberglass mast. It is made of 48 inch tapered sections, extends to 33 feet and weighs about 5 lbs.

Good light weight feed lines are important. 9913F or LMR-400 are two examples. Don't forget the interconnecting cables for your radio, amplifier, watt meter, etc.

Rotors are nice, but heavy. The HD 73 is compact and works well. The smaller Yaesu/Kenpro 500 AZ rotor is another possibility. Ropes can be used to turn (and elevate) the antenna, and are useful as tie downs. I recommend dacron rope. It's light and strong.

Bring a baby monitor. It allows you to go to the pool (or bar) and still be able to catch any short opening.

Other necessaries include lightweight headphones, a watt meter/SWR meter, VOM, soldering iron, solder, digital watch, spare connectors and fuses, electrical tape, cable ties, knife, razor blades, hose clamps, screw and nut drivers, wrenches, and spare parts for your antenna. K5AND recommends a "Linesman" combination tool. Don't forget a tape measure. It's tough to center elements without one.

Lap top computers have become more common in the past few years. They allow you to log your contacts and if an ISP is available, provide access to Propagation Logger DX Cluster, and E-mail. If moonbounce is an objective, a number of moon tracking programs can be loaded and used.

Three ring binder - I have found that a three ring binder is an invaluable aid. In the binder, which I always carry with me, I include log sheets, copy of my U.S. and foreign license, excerpts

from equipment manuals, print outs of moon position and meteor shower data, great circle azimuth and grid print outs, equipment lists, lined notebook paper, and DXCC prefix and country list. I put the license, moon information, and other documents I won't be writing on in plastic covers to protect them from spills, perspiration, and smashed insects.

2 METERS - With the exception of K6MYC and W6JKV, VP5 and ZF20C/2FZCP expeditions, this band is probably the most overlooked band for Caribbean contacts. Like 6 meters, 2 offers the opportunity for sporadic E and TE. It is far more practical than 6 for EME, and is quite good for meteors. In the spring and fall, 2 meters offers the possibility of tropo over exceptional distances.

Because 2 meters is my favorite band, I have had a fascination with working places not usually thought of as workable at that frequency.

The attached maps (Appendix A8-13) show what Caribbean and Maritime DX that can be worked from various cities in the eastern and mid eastern U.S. The scale of the map coincides with the maximum reliable range for single hop sporadic E and meteor scatter. As can be seen, from New York City, 16 DXCC countries are within 2500 kilometers (1563 miles). The total increases to 18 countries from my home QTH in FN 10, 20 for Washington D.C., 24 for Atlanta, and 46 for Miami. From St. Louis, 14 DXCC countries are within that distance. To give another perspective, maps centered on the Turks and Caicos (VP5) (Appendix 14) and Little Cayman (ZF2/ZF8) (Appendix 15) show what can be worked from those locations.

Equipment requirements for 2 meters are similar to 6 meters. A pair of lightweight antennas with 17+ dbd gain is a good minimum figure to plan on. I've used M² 2M5WL and 19XXX

antennas successfully. (Figures 7-8) More recently, cross polarity yagis have become popular. K6MYC has used 4 2MXP18 yagis on two of his more recent expeditions. Cross polarity yagis require additional phasing lines, a second power divider, and a polarity switching relay and control. In return they provide an opportunity to maximize the station efficiency.

M2 2M5WL Yagis at VP5/WA3HMK

Figure 7

Other antenna possibilities include Cushcraft, K5GW or K1FO designs. Remember side-by-side yagis, either horizontal or cross polarity, will require insulated crossboom ends. For antenna rotation and elevation, the Kenpro/Yaesu 5400/5500 series is a good choice. They are compact and reliable.

A kilowatt amplifier is also necessary for EME, Tropo, or meteor scatter. Choices include the Lunar Link by K1FO (1.5KW), Commander II (1KW) or homebrew. ARCOS amps are marginal but a possibility.

M2 2M19XXX Yagis at ZF20C-ZF2CP/ZF8

Figure 8

Two meter EME operation requires a receiver preamp; this in turn necessitates some precautions. One is to separate the transmit and receive lines. On the FT-847, this modification has been documented by DL4MEA on his website. Another technique is to use an inline preamp between your transceiver and amplifier. ARR makes such a unit; I mounted it on the side of my 2 meter Commander II amplifiers. (Figure 9)

W6JKV recommends that the feed line for the 2 meter antennas be brought out at the rear of the array to keep it as short as possible. He moves the antenna around to do this.

<u>432MHZ</u> - Unlike 6 and 2 meters, 432Mhz is virgin territory for Dxpeditions. EME and Tropo are the viable propagation modes. 432 offers the advantages of smaller antennas, but this is offset by the greater number of elements that have to be put together. Directive Systems, M², C3I, Cushcraft, and K3IWK all manufacture antennas suitable for portable use. K1FO has also described

the evolution and construction of a number of his designs in VHF/UHF and Above, Ham Radio, and QST.

ARR inline preamplifier mounted on Commander II Amplifier

Figure 9

Amplifiers for 432 are more limited. Lunar Link, ARCOS or homebrew are about the only choices. Low loss short feed lines are crucial and an antenna mounted preamplifier is mandatory. K1FO has described the assembly of a small but respectable 432Mhz EME array and station in Communications Quarterly. The information Steve presents in those articles is equally applicable to a portable EME or Tropo array.

RARENESS - The rareness of your proposed location is well worth considering. All other things being equal, activating a country which has never been on a particular band before, or hasn't been on for awhile is more fun than being just another DX station. But, to get your feet wet, a location which has had VHF activity may be the thing. Pileups can be fun, but offer the potential for real frustration if you aren't prepared for them. To check out the rareness of the place, you can

consult K5AND, W6JKV/5, and VE7BQH (for 2 meter EME), W3EP, KIFO (for 432 Mhz EME), or put a post on the Internet. Periodic surveys have been taken and published by the UK Six Meter Group (UKSMG); G3WOS or other UKSMG officers can help you out.

NON RADIO ACTIVITIES - If you are going to an island or country, don't neglect nonradio activities. Scuba diving, snorkeling, deep sea fishing, dining out, sailing, sight seeing and shopping enhance any trip. Plan to take time away from the radio, and do it. If you want to scuba dive, get your certification or refresher course before you go. It's cheaper and resort scuba courses do not allow you to dive elsewhere. Bring a camera, extra film and batteries, and binoculars. (Appendix A-7) Even if you stay at a resort, try to get around to a native restaurant to sample the real local cuisine. Spending a few hours in a local bar can be entertaining and informative. Sample the local music. Steel drums and reggae are great.

III. SUMMARY

VHF Dxpeditions to the Caribbean can be a fascinating and rewarding experience. You can experience different cultures, foods, and enjoy the radio in an atmosphere completely different from your home. Plan carefully, check everything out ahead of time and go for it.

APPENDIX

A1 Sample Equipment First

A2-4 Equipment Checklist

A5 Health Care Checklist

A6 Miscellaneous Items Checklist

A7 2 Element Quad For 6 Mtrs.

A8 Azimuth Map - New York City

A9 Azimuth Map - Lancaster, PA

A10 Azimuth Map - Washington D.C.

A11 Azimuth Map - Atlanta, GA

A12 Azimuth Map - Miami, Fla

A13 Azimuth Map - St. Louis, MO

A14 Azimuth Map - Providenciales Island

A15 Azimuth Map - Little Cayman Island

A16 Resources for Dxpeditions

Name _____ Date_____

Address_____

_____

(SAMPLE) EQUIPMENT LIST

MANUFACTURER	DESCRIPTION	SERIAL NUMBER	VALUE

EQUIPMENT CHECKLIST

A) Radio

Transceiver - HF/ VHF

Amplifier/Preamp

Spare Preamp(s)

Wattmeter/SWR Bridge

Muffin Fan(s)

Memory Keyer & Paddle

Interconnecting Cables, Clip Leads

Antenna(s) W/Spare Element Mat'l., Keepers, Hdwe.

Switching Power Supply 110/220v. Input w/Connectors & Adapters

Feedline For Each Band - 9913F/LMR-400

Azimuth & Elevation Rotors - HD 73, Kenpro/Yaesu 5400

Rotor Cable

Power Divider/Phasing Lines - (EME)

Antenna Support - Tower/Fast Mast/DK9SQ Mast

Lt. Wt. Headphones

TVI Filters - I.C.E./K1UHF

Spare Fuses & Connectors - Coax, Molex, Etc.

Baby Monitor

VOM

Compass

Leatherman

Rope - Dacron

Packing Tape

Equipment List, Cont.

B) Ring Binder

Log Sheets

U.S. & Foreign License

Exerpts From Equipment Manuals

Great Circle Azimuth & Grid Printouts

Equipment List(s)

Printout of Moon Position, Meteor Shower Data, Etc.

Repair List

C) Computer

ISP

Moontracking/Meteor Shower Programs

Logging Program

C.W. Keyer Program

D) Tools

Soldering Iron w/Solder

Screw Driver(s)

Nut Driver(s)

Wrenches - adjustable

Hose Clamps

Electrical Tape

Tape Measure

Cable Ties

Knife/Razor Blade

Mini Hacksaw

HEALTHCARE CHECKLIST

Prescription Medicine - sufficient for trip plus a few extra days

Copy of Prescriptions

Health Insurance Card

Suntan Lotion/Sunblock

Sunglasses

Prescription Glasses - Extra Pair

Bug Spray/Repellant

Antacid

Band-aids

Aspirin

Topical Antibiotic

Anti-Diarrhea Medicine

Personal Toiletries

Tweezers/Nail Clippers

Long Sleeve Light Cotton Shirts & Pants

Extra Underwear

Large Brim Hat/Baseball Cap

MISCELLANEOUS

Camera w/Extra Film, Batteries & Lens Cleaner

Binoculars

Scuba Certification Card

Flippers, Mask & Snorkel

Driver's License (Picture ID)

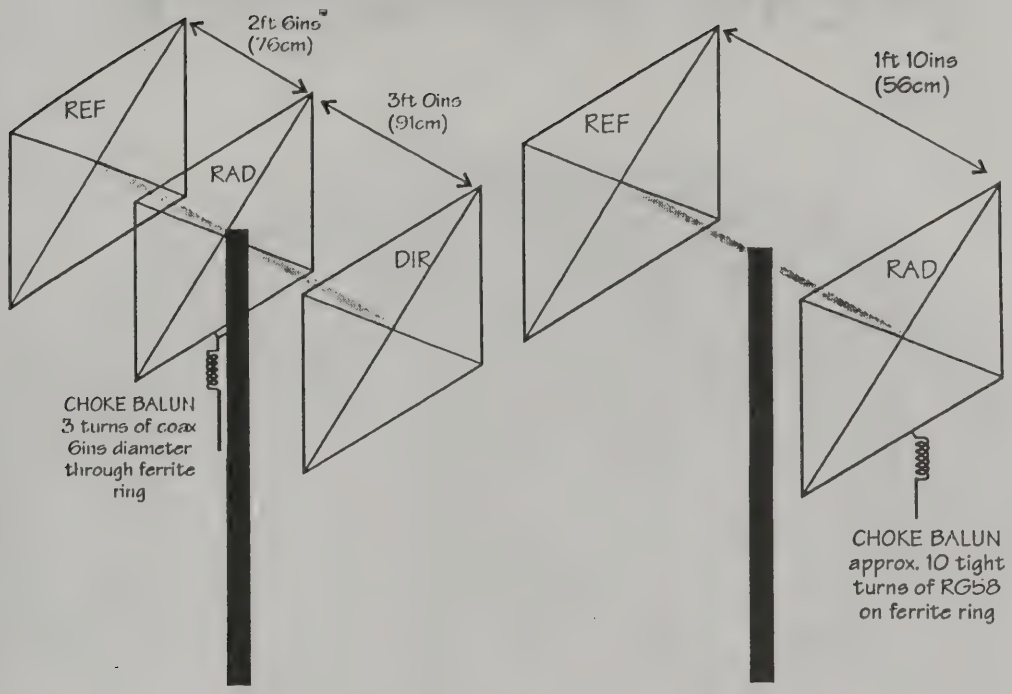
Traveler's Checks

Local Currency

Pens

Books

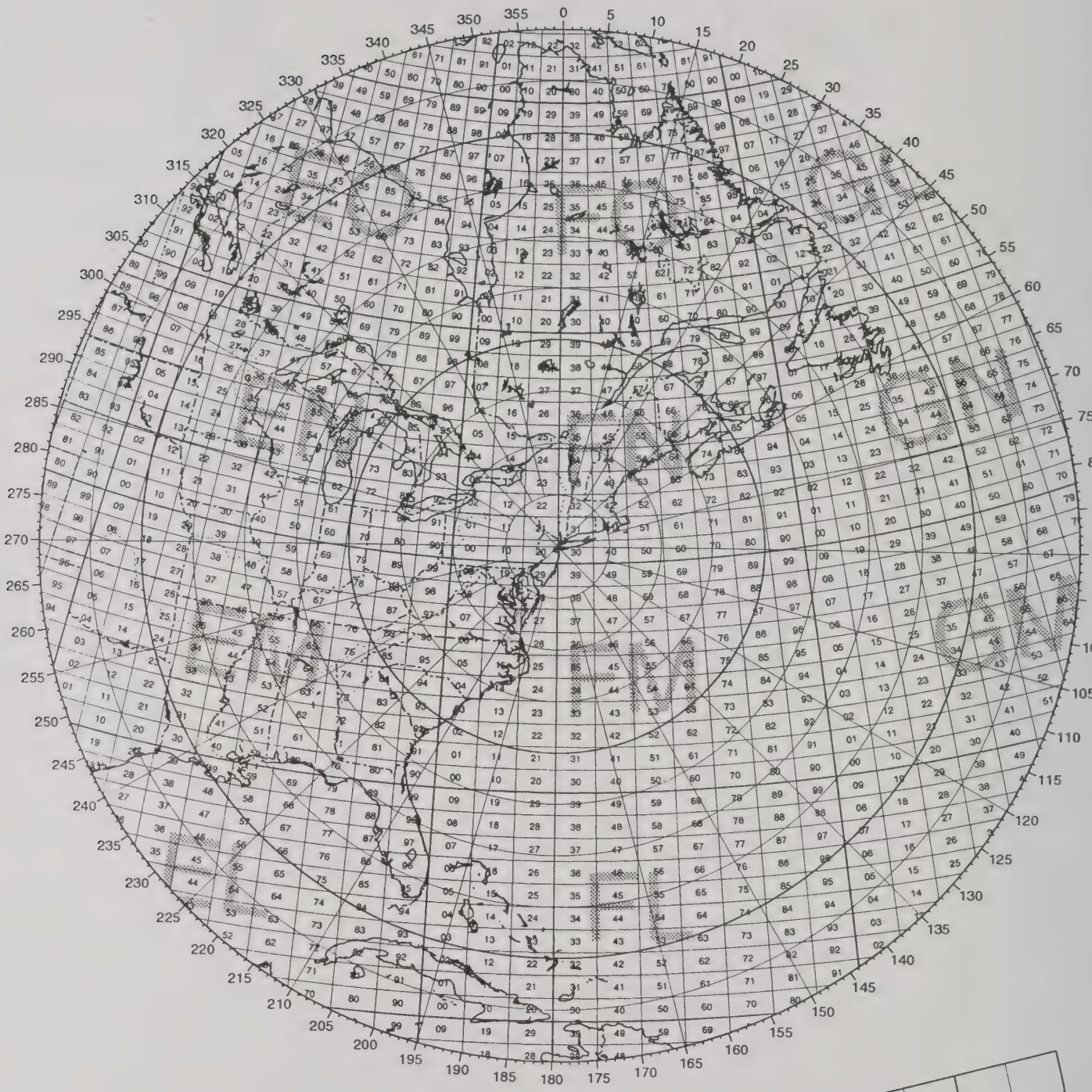
Trash Bags



Reflector	20ft 6ins	(6.25m)	Reflector	20ft 8ins	(6.30m)
Radiator	19ft 11ins	(6.07m)	Radiator	19ft 10ins	(6.05m)
Director	19ft 7ins	(5.97m)			
Forward Gain	7.5-9.0dbd estd.		Forward Gain	6-7dbd estd	
F/B	12.0db		F/B	15018db	
Min. SWR at 50.140MHz			Min SWR at 50140MHz		
2:1 SWR bandwidth approx 400kHz			2:1 SWR bandwidth approx 1MHz		
Feeder	RG213		Feeder	RG58	

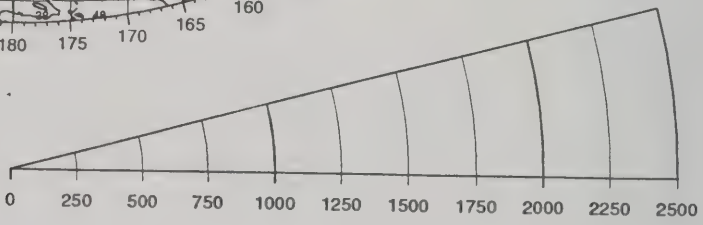
Dimensions for G3HBR's two- and three-element quads

New York, NY



FN20XR

2500 km



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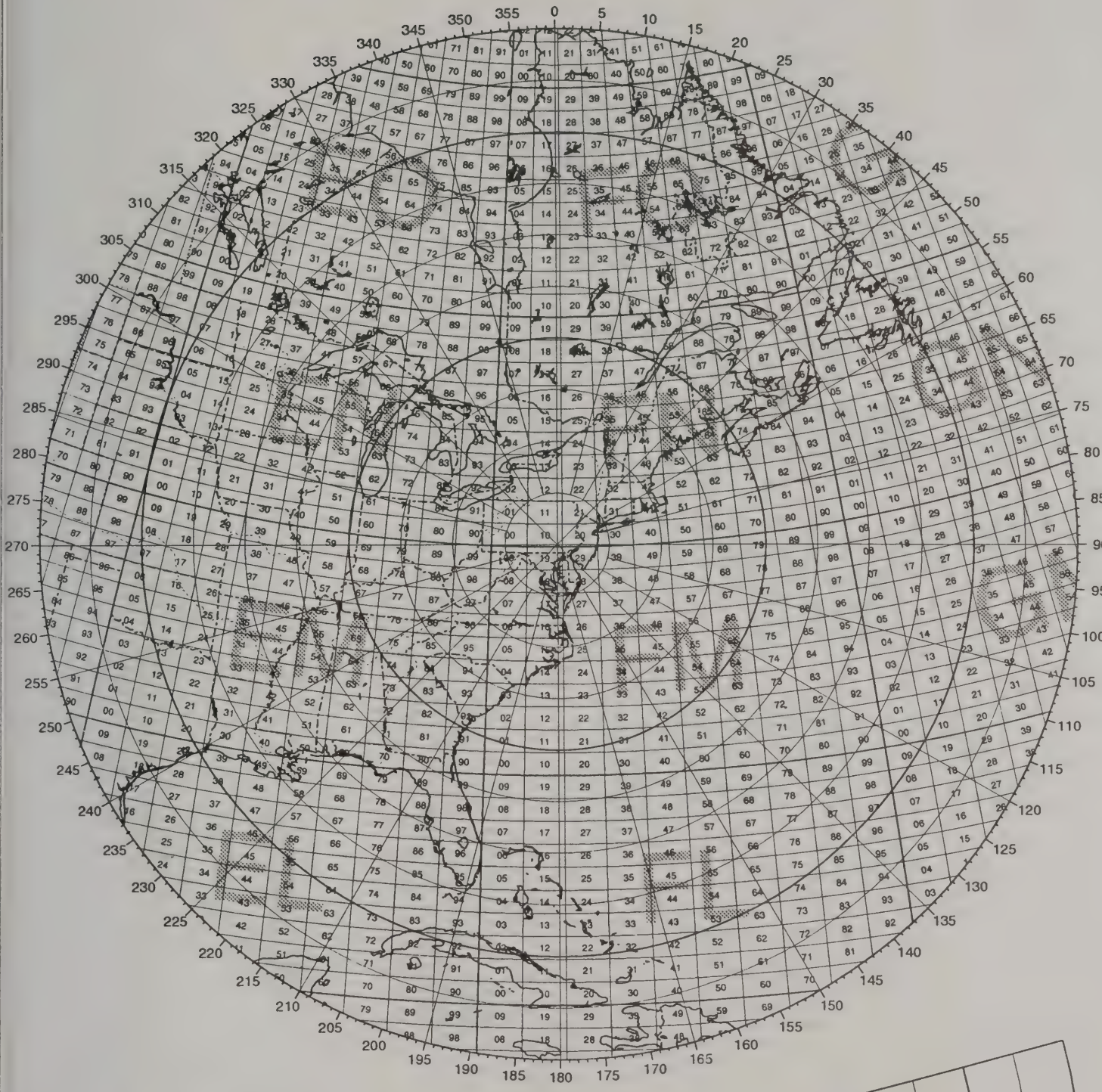
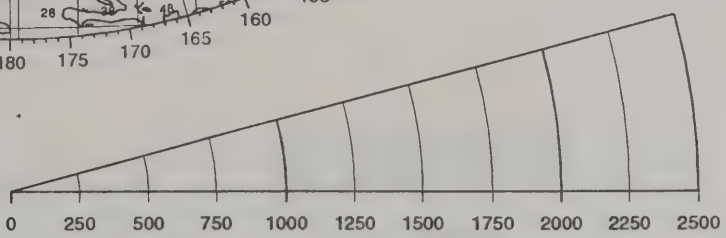
Lancaster, PA



FN10UC

2500 km



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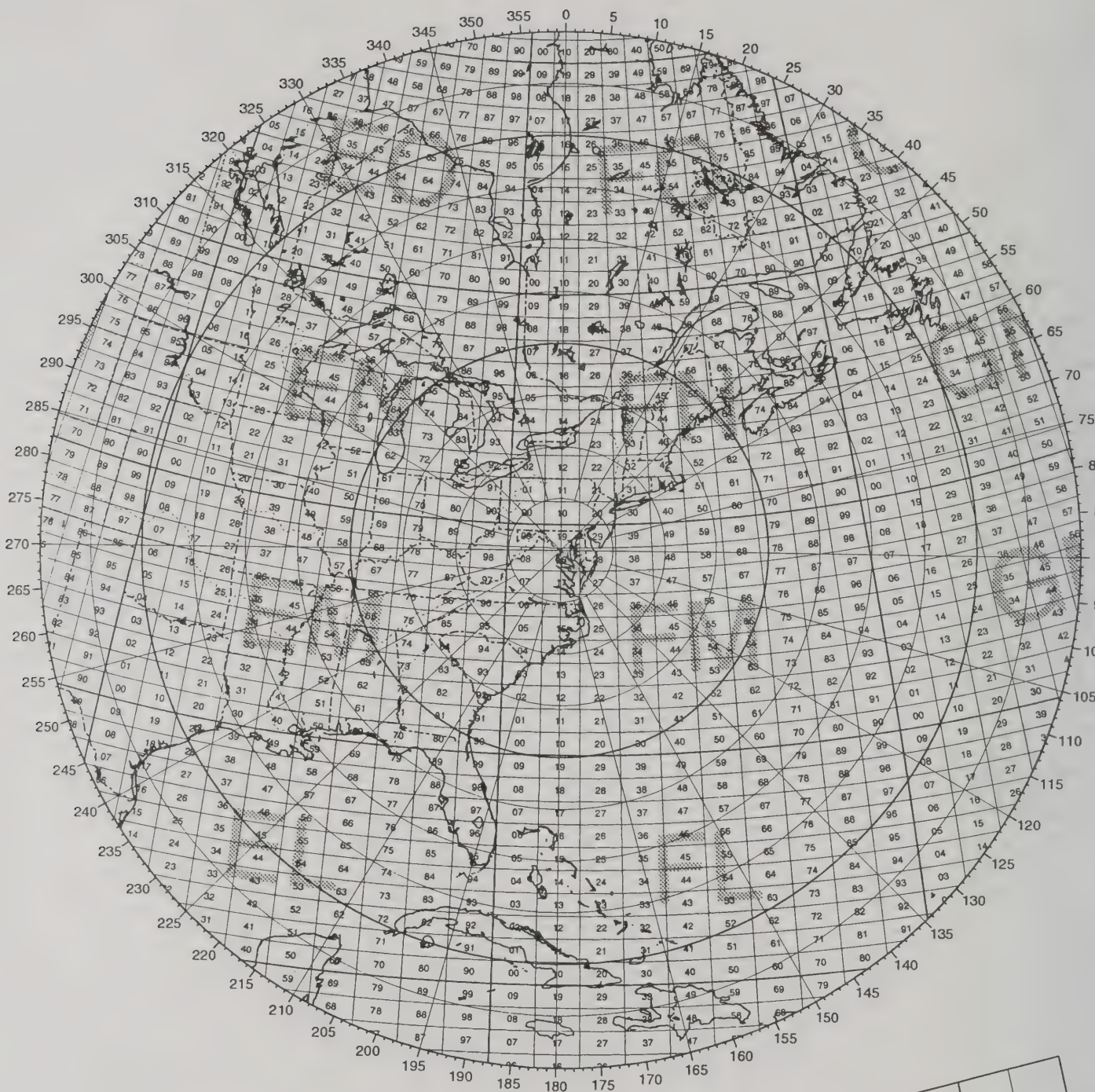
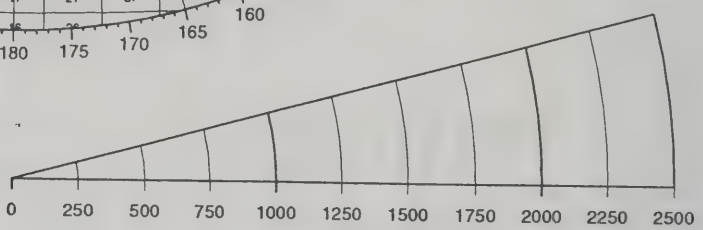
Washington, D.C.



FM18LV

2500 km



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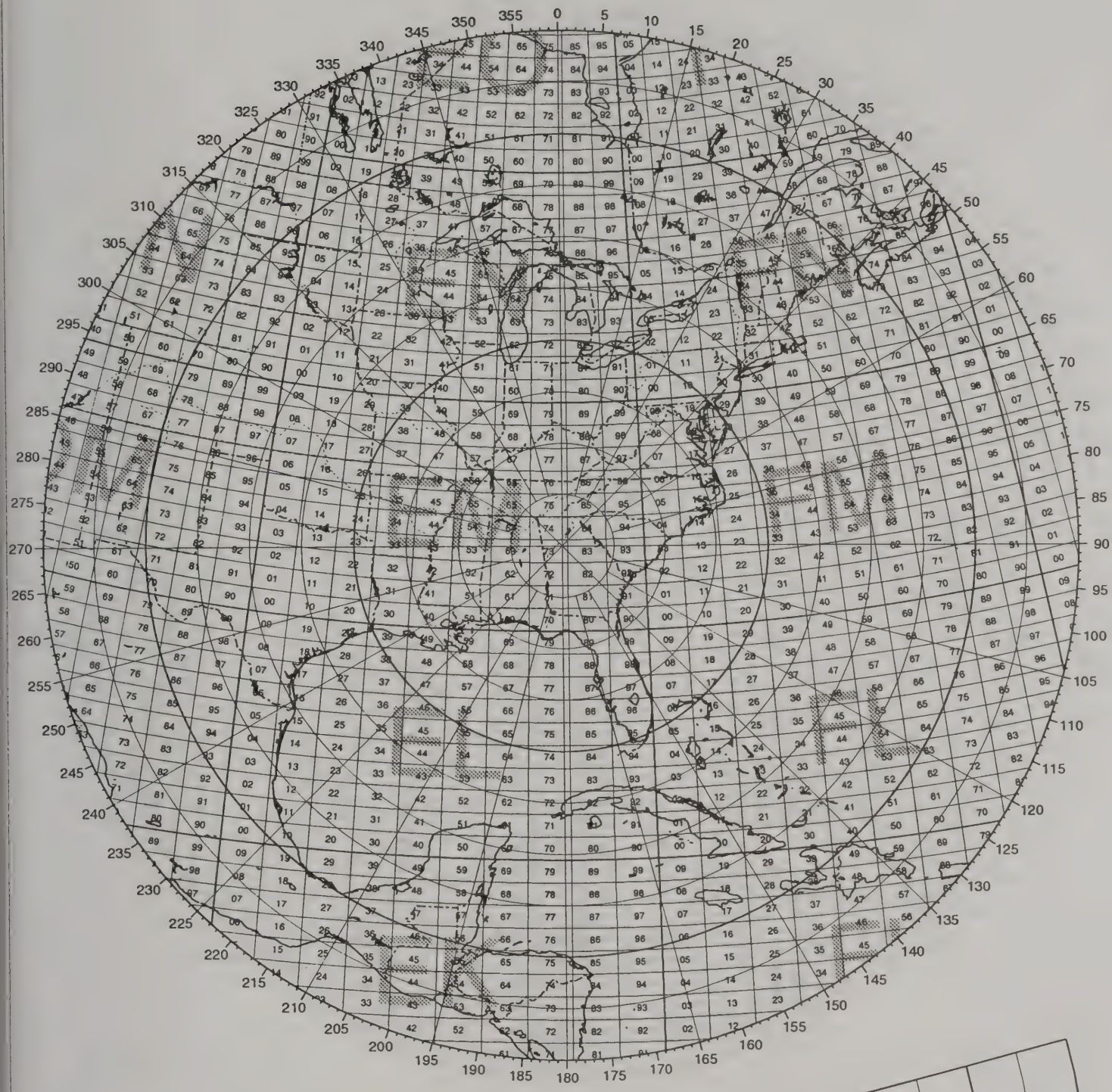
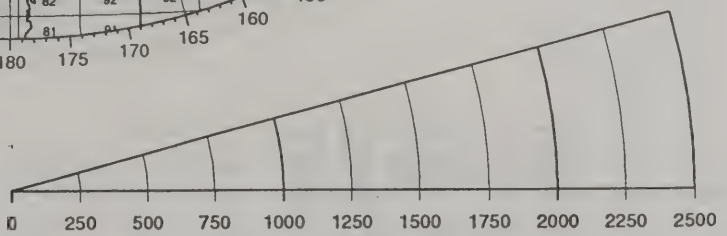
Atlanta, GA



EM73UR

2500 km



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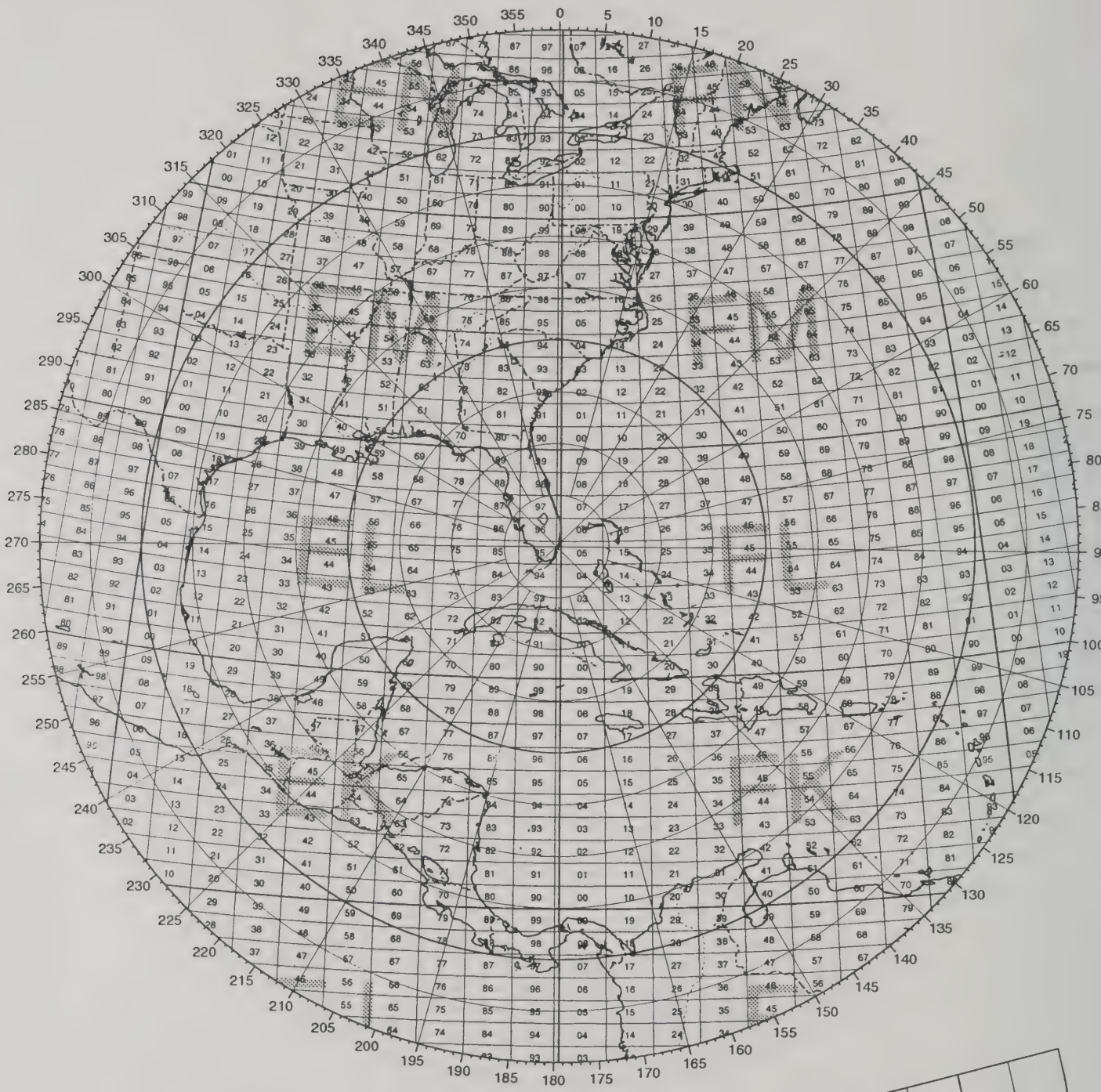
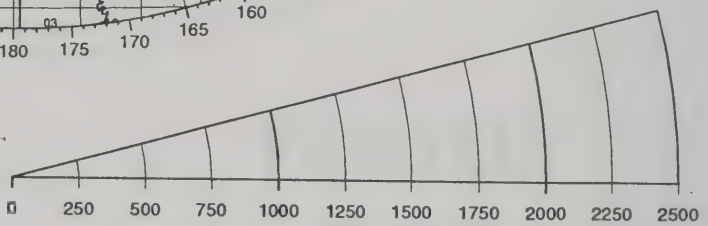
Miami, FL



EL95VS

2500 km



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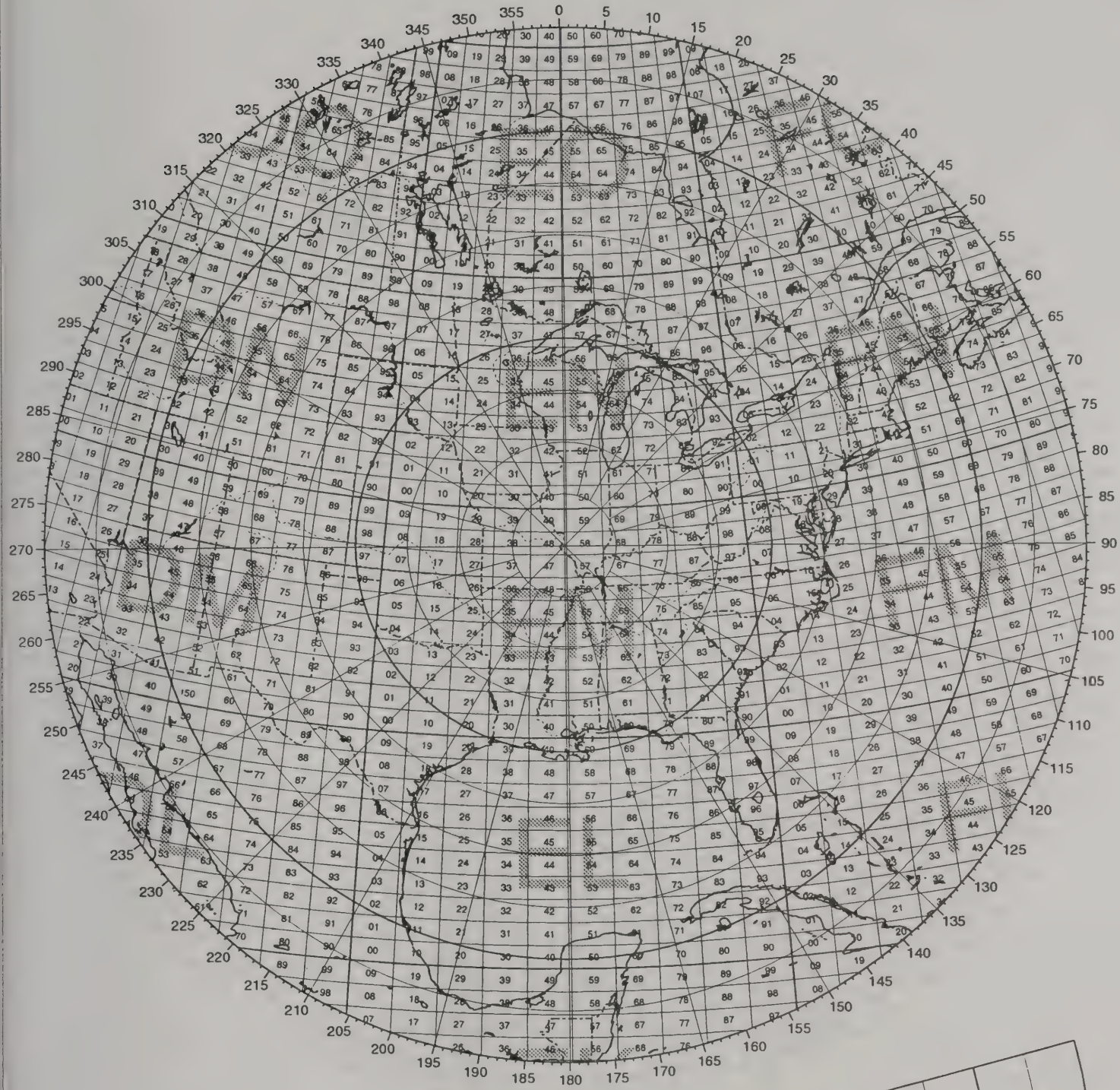
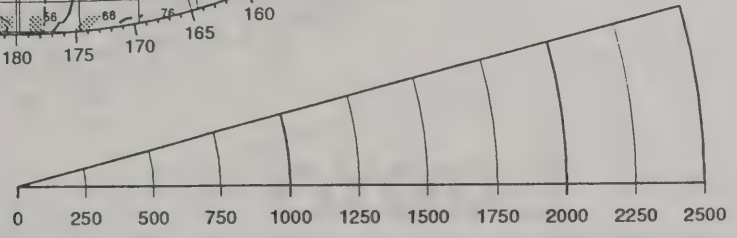
St. Louis, MO



EM48WJ

2500 km



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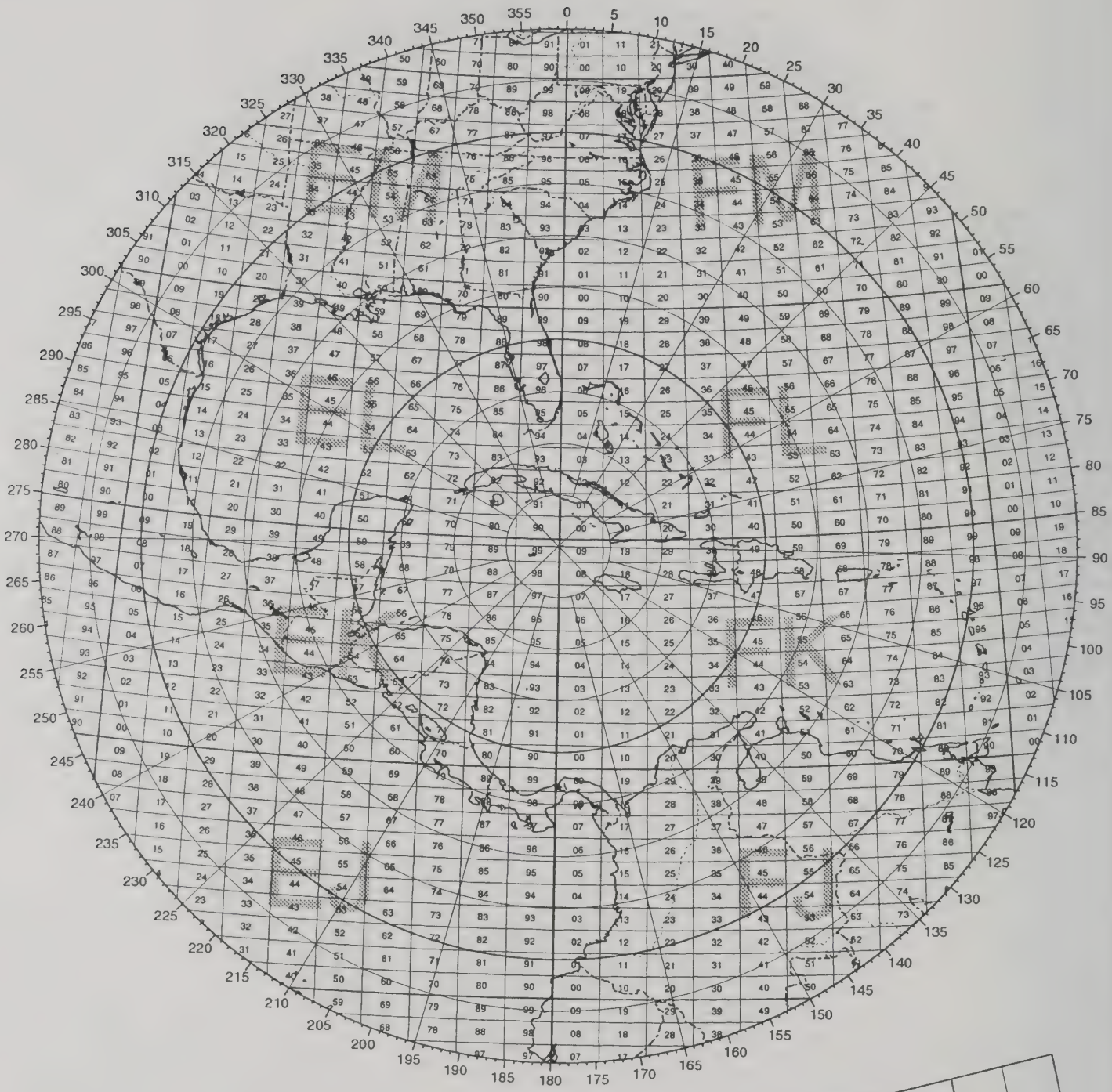
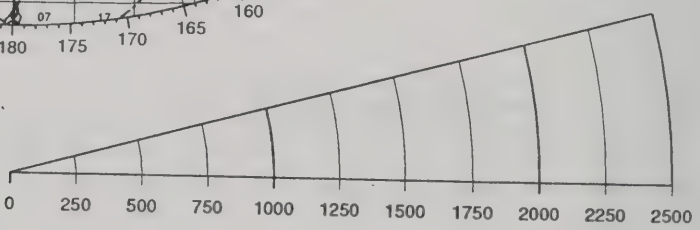
Little Cayman Is.



EK99XQ

2500 km



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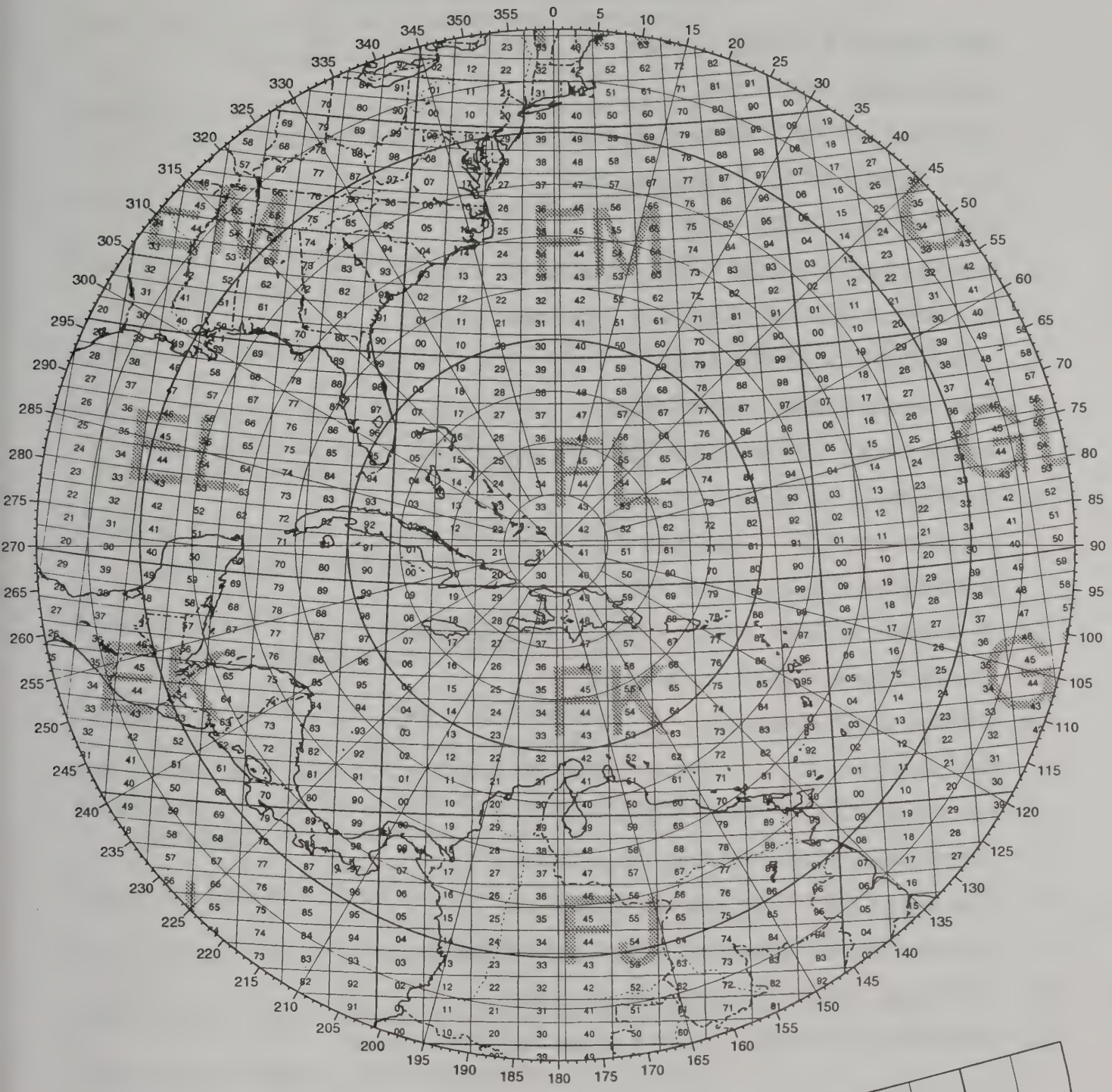
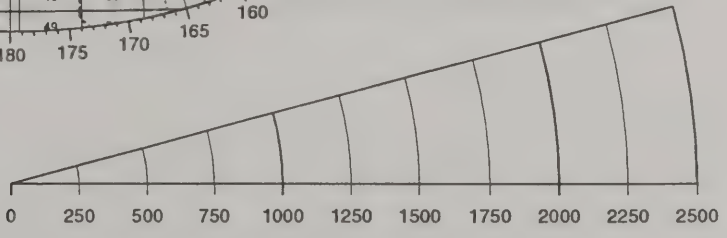
Providenciales Is.



FL31UT

2500 km



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RESOURCES FOR VHF DXPEDITIONS

1. Dale Baldwin, WBOQGH Antennas
2. Dave Blaschke, W5UN EME
3. Alan Bond, WB4GNT - MaxGain Systems - Fiberglass Rod & Tubing
4. Lance Collister, W7GJ - Dxpeditions, EME
5. Gary Crabtree, KB8RQ - EME
6. Lionel Edwards, VE7BQH - EME, Antennas, Net Control
7. Dick Hanson, K5AND - Amplifiers, Dxpedition Operating
8. Peter Ibelings - Solid State Amps
9. Norm Jeweler - Norm's Rotor Service
10. Joel Knoblock - RF Connection - Cable & Connectors
11. Steve Kostro, N2CEI - DEM
12. Jay Liebmann, K5JL - Amplifiers
13. Bob Magnani, K6QXY - 6 Mtr. EME
14. Dave Olean, K1WHS - Directive Systems Antennas, EME
15. Charles Osborne - UHF Rcvrs. & Xmtrs.
16. Joe Pater, K8JP Dxpeditions
17. Steve Powlishen, K1FO - Antennas, Lunar Link Amplifiers, Operating Especially 432 Mhz
18. Ray Rector, WA4NJP - EME - 6 mtrs. & up
19. Harry Schools, K3HS (ex KA3B) - Dxpeditions
20. Mike Stahl, K6MYC - M^2 Antennas, Dxpeditions
21. Pat Stein, N8BRA - Command Technologies Amplifiers
22. Jim Treybig, W6JKV/5 Dxpeditions, Operating
23. Tom Whitted, WA8WZG - Hardline Connectors, VHF Contests

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Smith, Michael, VE9AA. "Perspective on CY9AA" Six News November 1997: 30-35.

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Aligning Preamps Using an FM Receiver

Bruce Randall WD4JQV

Aligning a preamp for best noise figure is difficult to do without a noise figure meter. Alignment "by ear" does not often yield optimum results. Very few preamps have good noise figure when they are aligned for best gain.

I have used an FM receiver along with a weak signal source to adjust preamps for optimum noise figure. Everyone knows that FM is not optimum for weak signal work; so how do we use FM to adjust a low noise preamp?? The FM detection threshold that buries weak signals is the key.

Consider an unmodulated carrier along with noise of slightly smaller level after the IF filter in a receiver. When this hits the limiter stage the stronger signal will "win" and determine the output frequency of the limiter. (Capture effect.) Noise is random in nature with intermittent peaks to typically 7 times the RMS value. This causes an intermittent popping in the audio as the noise signal occasionally wins control of the limiter. A very small change in signal to noise ratio (S/N) makes a noticeable change in the popping rate. (Ref , Attached from February 1982 QST magazine.)

With an adjustable weak signal source, the level of signal into the preamp is adjusted so the receiver is close to the FM threshold. Now the preamp is adjusted to reduce the popping rate. The signal source must be set lower and lower to remain in the threshold region as the preamp noise figure improves. Keep the signal level right where the smallest change in receiver S/N causes the most noticeable effect.

Note that if the receiver has a poor limiter stage this procedure will not work. Fortunately, all modern amateur FM receivers, that I have seen, have good limiters with plenty of gain before the limiter.

Also of interest: Some microwave satellite receivers use "threshold extension" FM detectors. These move the threshold to a lower level and soften it. It does not have the region where the signal suddenly jumps out of the noise. This is very good for the intended application, but is not useful as a preamp tuning tool. I believe that no manufacturer of amateur transceivers has used this type detector YET!!!

Having a signal source that is smoothly adjustable to very low output is a requirement. The HP_608, URM26, and other surplus generators often leak enough signal around the output attenuator to bring a sensitive receiver above its FM threshold. Frequency drift is also a problem. If you have one of these generators, try it, it may work OK. Adding an external attenuator on the generator may help.

My cheap signal source is a 16MHz crystal oscillator with a simple waveguide beyond cutoff attenuator. If I were building this device today, I would use a 48MHz micro processor clock oscillator. (See the sketch on the last page.) This oscillator produces harmonics at 144MHz, 432MHz, and 1296MHz. A 10MHz oscillator produces

harmonics at 50MHz and 220MHz... Then the FCC moved us to 222, oh well. THIS OSCILLATOR MUST BE BATTERY POWERED! Power supply wires will couple out enough signal to ruin the isolation of the attenuator. The battery and oscillator are mounted on a plastic 12" ruler.

A scrap of 1.25 or 1.5 inch ID aluminum tubing about a foot long is the heart of the output attenuator. An "N" connector is mounted to a metal cap on one end of the tubing. A 47 ohm 1/4 w carbon resistor in series with a small coupling loop formed from the resistor lead are connected across the connector pin to ground. The coupling loop should be about 1/4th inch diameter. The exact size is very non-critical. A good UHF/Microwave 10dB pad is put on the connector to assure a good 50 ohm source for the preamp. It is important that no wires or other metal parts from the oscillator extend outside the tubing or it will spray lots of signal everywhere. This leaked signal WILL find its way into the preamp or receiver. No metal part of the oscillator circuit can touch the tubing wall or the attenuator will be jumpy and intermittent. Note that above some frequency the tube will become a *functioning* waveguide, and not an attenuator!!. Above 2GHz a smaller diameter tube may be needed. As the ruler is pulled out of the metal tube, moving the oscillator away from the output loop, the attenuation increases linearly at about 30 dB per inch.

Don't try to use a weak off the air signal. You can't control the level accurately and there is always minor changes of signal level due to propagation effects.

A look at pros and cons of this method:

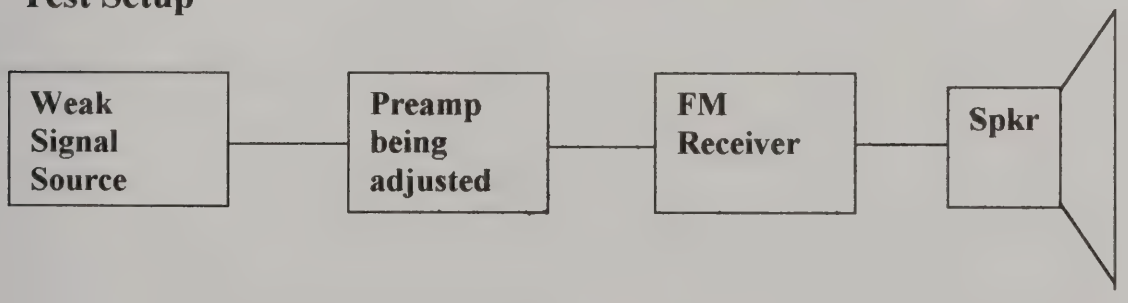
PRO

- Based on S/N so best noise figure is attainable
- Cheap
- Signal source fits in my toolbox

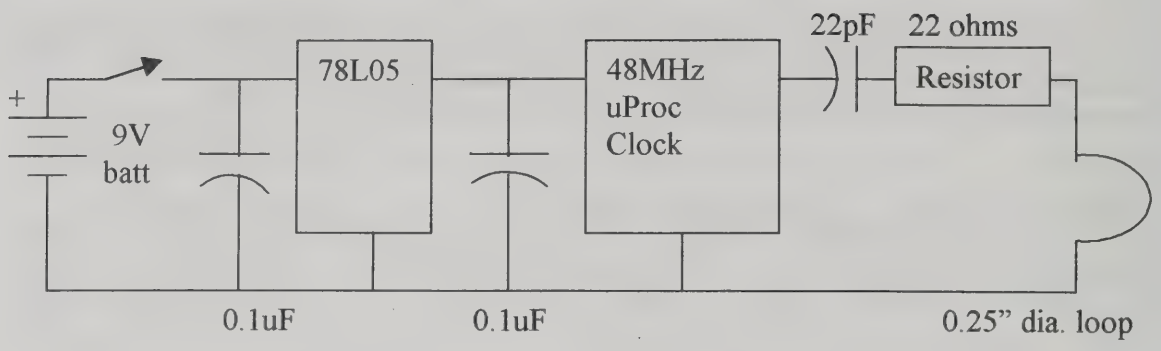
CON

- An undesired harmonic of the oscillator could fall on top of a receiver spurious response, and fool you into optimizing noise figure at the WRONG FREQUENCY!
- This is **NOT** a measuring instrument, but a crude calibration on each band is possible based on the plastic ruler position.

Test Setup



Signal Source Circuit



Ref 1 Bruce Randall WD4JQV, "The Merits of FM vs. SSB", Technical Correspondence, QST, February 1982, P52.

THE MERITS OF FM VS. SSB

☐ On several occasions I have heard discussions about the relative merits of fm and ssb for vhf communications. Most experiments contrived to settle the issue show that fm is "better."

A good theoretical analysis can be found in ref. 1, chapters 9 and 10. Eq. 9.2-22 is of special interest:

$$\gamma_{fm} = \frac{S_o/N_o}{S_i/N_m} = \frac{3\beta^2}{2}$$

where

γ_{fm} is the communication efficiency referenced to a baseband system.
S_o/N_o is output signal to noise.
S_i is signal power at the limiter input.
N_m is noise power in the information bandwidth at the limiter input.
β is the modulation index.

Note that $\gamma_{ssb} = 1$ (ssb is frequency translated baseband); therefore, γ_{fm} is the improvement factor for fm over ssb. Applying this to a 5-kHz deviation, 3-kHz bandwidth system:

$\beta = 1.67$ and
$\gamma_{fm} = 4.17$ or 6.2 dB

In practice fm is about 3 dB better because of the 75 μs deemphasis, lowering the effective audio bandwidth for noise (see ref. 2, page 21-12, for math). This gives an fm-system advantage of about 9 dB over an ssb system for strong signals.

An fm system shows a threshold effect that causes the performance to degrade rapidly below 7 dB input signal-to-noise ratio. The fm i-f filter is about four times as wide, or 6 dB wider, so the ssb system has 13 dB signal-to-noise ratio at the fm threshold. Ref. 1 covers threshold effects in chapter 10. The following experiment verifies the behavior predicted by the theoretical analysis.

Fig. 2 shows the setup for the experiment. The agc in the Drake 1A receiver was disabled to allow reliable signal-to-noise measurements. The i-f strip from a Motorola H23 was retuned to 28.120 MHz and used as the fm i-f in the experiment. The H23 strip had a 5-kHz deviation i-f filter.

Fig. 3 is a graph of the measured S + N/N vs. input level for both systems. The theoretical graphs are S/N and the measured graphs are S + N/N. This causes a slight difference at low levels. Note that above the 20 dB quieting point fm provides significantly better system performance, and below that becomes noisy very quickly. The ssb system remains usable about 8 dB below the level at which the fm system becomes unusable. This means about six times the power level needed for marginal ssb communications is needed for fm. The minimum level that can be detected is about 12 dB lower for ssb. This is important because it can be a clue to rotate your antenna toward the other station. On long paths, multipath distortion can render fm unintelligible, while ssb would be almost unaffected.

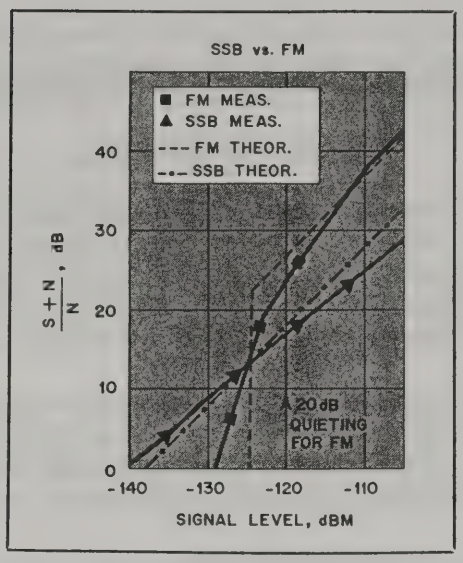


Fig. 3 — Curves for the measured signal-to-noise ratio versus the signal input level for both systems discussed in the text.

Besides offering better signal-to-noise ratio, an fm signal also lends itself nicely to reliable squelch circuits because of its constant total power. A Touch-Tone pad signal would not survive the small frequency errors typical of ssb systems. One should note that both systems have their unique advantages and disadvantages, and both systems play important parts in today's vhf bands. — *Bruce Randall, WD4JQV, Alpharetta, Georgia*

References

[1]Taud, H. and D. L. Schilling, *Principles of Communications Systems.* (New York: McGraw Hill Book Company, 1971).
[2]*Reference Data for Radio Engineers, Fifth Ed.* Indianapolis: Howard W. Sams & Co., Inc., 1969).

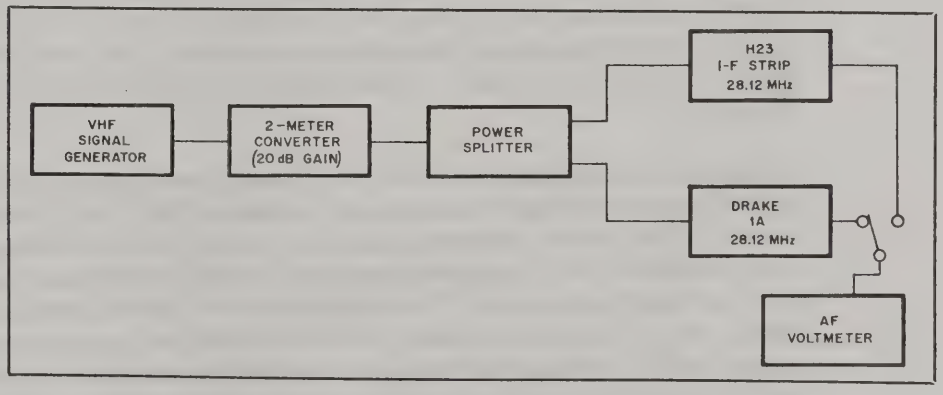


Fig. 2 — Block diagram of the test setup used for the experiment described in the text.

From February 1982 QST

A Switchless Transceiver – Transverter Interface

Reed Fisher, W2CQH

Many VHF/UHF/microwave SSB stations consist of a 100 watt HF transceiver interfaced to an appropriate transverter and power amplifier. It is well known that this is a potentially dangerous interface. An improper circuit can damage the transceiver and/or mixer(s) within the transverter. Interfaces employing sequenced IF switches have been described in the literature (1),(2). These circuits are complex and require transceiver-derived keying and (sometimes) RF sensing.

A different and safer approach is a switchless interface that works alone, independent of transceiver keying and RF output. Fig. 1 shows the present configuration of the W2CQH 432 MHz station. A Yaesu FT-900 transceiver is connected to a homebrew 432/28 MHz transverter via a resistive attenuator (pad) and isolator. The interface is switchless, hence essentially foolproof.

In the transmit mode the FT-900 is adjusted to deliver about 30 watts (+45 dBm) PEP into the 50 dB pad. The first stage of the pad is a 100 watt, 50 ohm load (e.g. Heath Cantenna) which absorbs most of the 30 watts. The -5 dBm 28 MHz power, leaving the pad, drives the transverter input (J4) to become the final 432 MHz transmit signal.

In the receive mode the 28 MHz receive band, leaving J3, passes un-attenuated through the isolator box and enters the FT-900. The isolator must possess some interesting characteristics:
-The output circuit must withstand 100 watts (200 volts p-p) without damage,
-The reverse loss should exceed 50 dB to prevent mixer damage,
-The forward gain should be at least 0 dB,
-The 3rd order intermodulation performance should be comparable with the FT-900,
-A broadband, untuned circuit is desired.

Passive ferrite isolators are available for IFs above 400 MHz. At 28 MHz an active, unilateral amplifier must be used. High voltage FET and bipolar transistors were first investigated, but were found to have excessive output and feedback capacitances. Also, solid state devices are intolerant of even brief accidental overloads. A failed transistor, short circuiting the 50 ohm load, can damage the transceiver.

The pentode vacuum tube is a better device. Its output and feedback capacitances are very low (5pf,.0035pf) and the plate circuit can easily withstand 500 v. Fig. 2 shows the isolator circuit diagram. The 12AU6 (or 12BA6) pentode was chosen since it is readily available at most hamfests. The 6 volt equivalent (6AU6) can also be used if a 22 ohm, 2 watt voltage dropping resistor is put in series with the filament (pin 4). The requirement for +12 volt dc operation means that the tube must be used in a non-standard mode. The tube is connected as a tetrode: grid 3 (pin 2) connected to plate (pin 5) . Pentodes that have grid 3 internally connected to the cathode (e.g. 6AK5, 6AG5) must not be used since the zero-biased grid reduces plate current.

With grid 1 biased at 1 ma. the plate current Ip = 3 ma. and the transconductance gm = 3000 micromhos, values near those obtained with normal (high voltage) operation. However, the penalty paid for grid 1 forward bias is low input impedance (about 500 ohms). Thus the tube is similar to a poor bipolar transistor (low input impedance and high output impedance). The tube is "poor" because a transistor, biased at 3 ma., has a theoretical gm = 110,000 micromhos! The theoretical available gain of the tube, alone, driving the 50 ohm load is about –16 dB. Available gain = amplifier available output power/source available power. Available gain is used for receive amplifiers since the load impedance (FT-900 input) is unknown.

The low tube gain necessitates the placement of a transistor amplifier ahead of the tube. The 2N-918 NPN transistor was chosen because it is readily available and its RF bandwidth easily goes to 50 MHz. The final 2-stage isolator circuit, shown in Fig. 2, has these measured characteristics:

-The output circuit withstands 300 watts cw without damage.
-Reverse loss > 60 dB., 12 vdc on or off.
-Forward gain = 2 dB, flat from 5 to 35 MHz. Gain = -2dB at 50 MHz
-3rd order intercept point, IP3 = +5dBm.

IP3 = +5dBm is consistent with solid state transceivers. For example, two QST Product Reviews (3)(4) report that IP3 = -2.8 dBm for the Kenwood TS-430 and IP3 = + 22 dBm for the Yaesu FT-900.

The Fig. 2 circuit was built on a 1/32" x 2" x 5" aluminum plate which was screwed to a chassis box. BNC connectors were used. The inductor L2 must be physically large to withstand the high RF voltage. Wind 33 turns of #22 AWG wire on a ½ inch dia. form. Do not use a ferrite core choke. Diode CR1 increases the cold (dc off) reverse loss.

References.

1.-Z. Lau, KH6CP,"A VHF/UHF/Microwave Transverter IF Switch", QEX, Aug. 1988, pp 3-4.
2.- P. Wade, N1BWT,"A Fool-Resistant Sequenced Controller and IF Switch for Microwave Transverters", QEX, May 1996, pp 14 – 22.
3.- QST Product Review, Kenwood TS-430, QST, Mar. 1984, p. 40.
4.- QST Product Review, Yaesu FT-900, QST, Feb. 1995, p. 60.

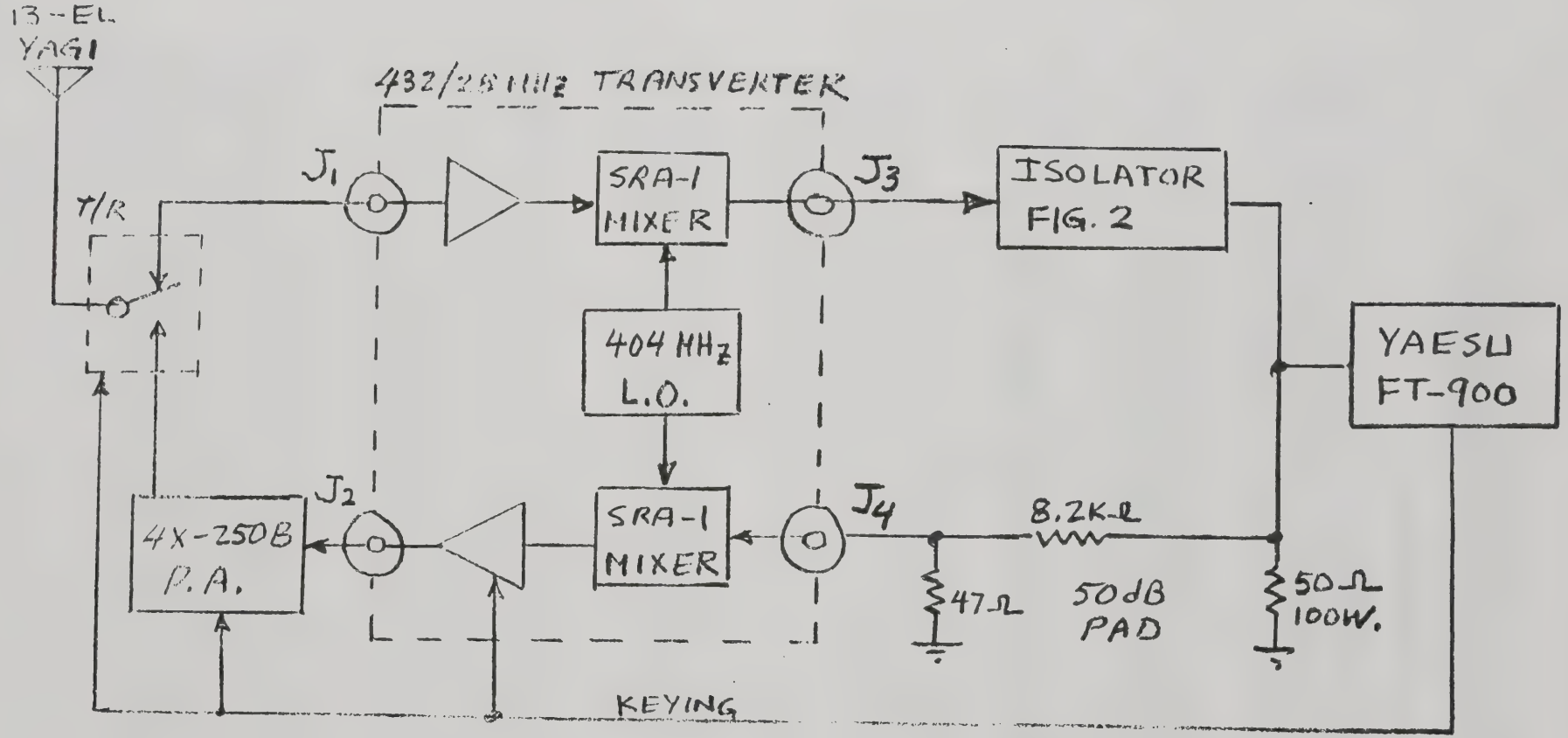


FIG. 1 W2CQH 432 MHz STATION

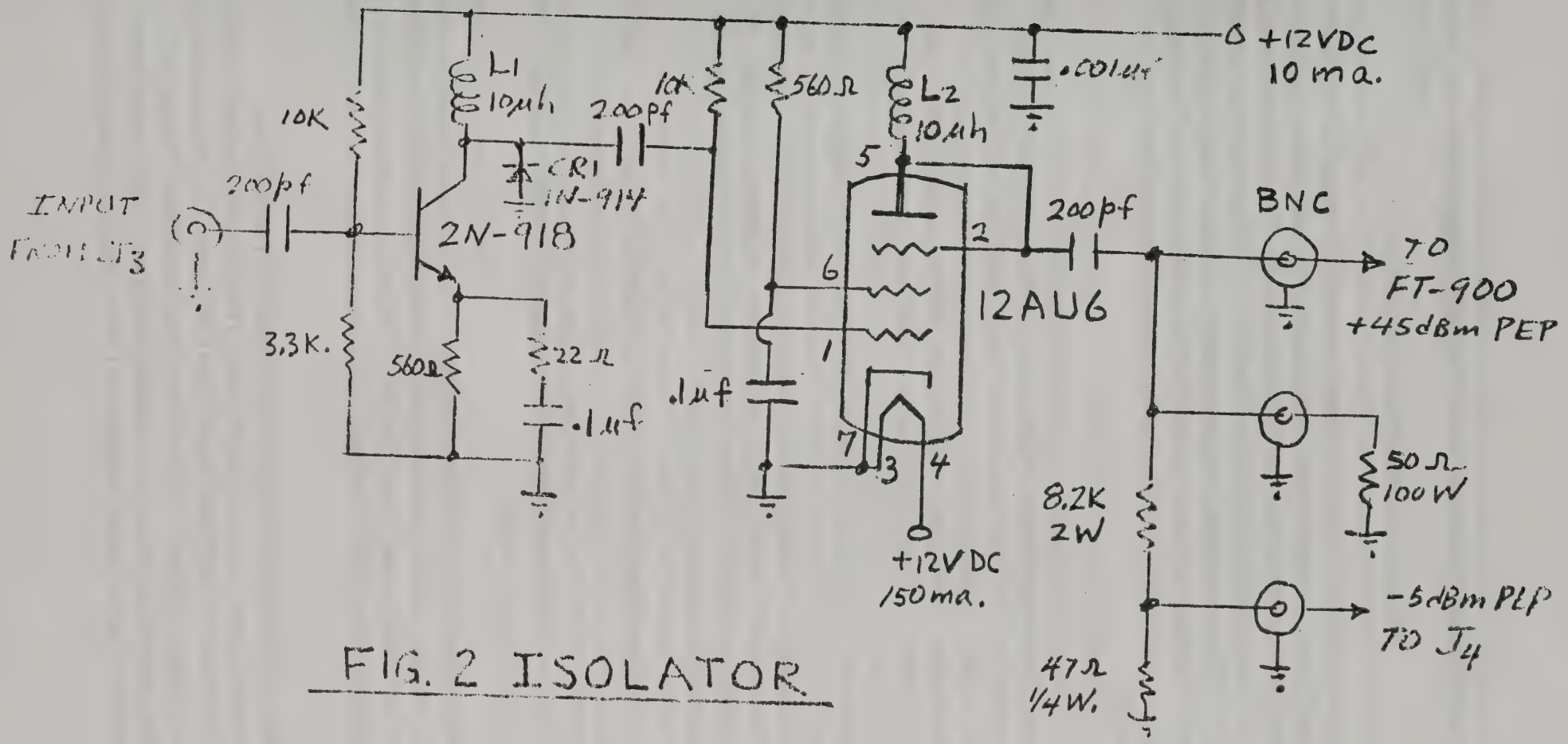


FIG. 2 ISOLATOR

W2CQH 2/14/00

SOUTHEASTERN VHF SOCIETY CONFERENCE

NOISE FIGURE MEASUREMENT

Noise Figure is an important parameter to anyone involved in the reception of weak signals. The noise figure of a device or circuit is defined as the ratio of the signal-to-noise ratio at the input to the signal-to-noise ratio at the output. Thus the noise figure of a device or circuit is the degradation in the signal-to-noise ratio as the signal goes through the device or circuit. A perfect amplifier would amplify the noise at its input along with the signal equally. A realistic amplifier, however, adds some extra noise of its own and degrades the signal-to-noise ratio. A low noise figure means that very little noise is added by the amplifier.

Most hams do not have or have access to the equipment required to measure noise figure, but do have and use low noise preamps in their station. In order to assist hams with checking their preamps and verifying they work and meet specifications, the conference committee decided to obtain equipment for noise figure measurement and make it available at the conference. Also, a group can't hold a VHF conference and not have noise figure measurements. This activity also adds a lot of fun to the conference.

The conference has been very fortunate to have Agilent Technologies support this effort by providing us an HP 8970B Noise Figure Meter. This year we are only going to do 50 MHz to 1296 MHz testing for two reasons. First, because history has shown that these frequencies will cover about 95% of the preamps tested at the conference. Second, to reduce the shipping cost and handling of the additional equipment required to do noise figure measurements at microwave frequencies.

The HP 8970B Noise Figure Meter is a microprocessor controlled, triple conversion receiver that is tunable from 10 to 1600 MHz. It works by turning an external noise source at the input to the DUT (Device Under Test) on and off. It then measures noise power in a 4 MHz bandwidth at the output of the DUT and makes the calculations necessary to obtain noise figure and gain.

In noise figure measurements, the cold source temperature is the physical temperature of the noise source. In the past, noise figure meters have assumed the physical temperature is 290K to simplify calculating noise figure. The HP 8970B can use a value selected by the operator or a default value of 296.5K when calculating noise figure. We are using the default value.

Mismatch uncertainty is often the most significant uncertainty in noise figure measurement. The noise source we use is the HP 346A. This source is designed to have a very small change in reflection coefficient from ON to OFF states. This minimizes errors when measuring noise figure and gain as a function of input impedance. The use of adapters in the signal path during testing will degrade the accuracy of the measurement. We will try to provide the highest quality adapters and cables available. One note about

adapters, there is a myth that gold plated adapters are the best. Machining tolerances and dielectric materials determine the quality of any connector or adapter, not the plating material used.

When the noise figure of a preamp is small, any uncertainty can account for an error in the measurement. As previously mentioned, mismatch uncertainty caused by the noise source, cables and connectors is one source. Other sources of uncertainty are noise from nearby electrical devices, interference from nearby radio transmitters, as well as the inherent accuracy of the HP 8970B itself which is specified as +/- 0.1 dB. As a result, the goal of performing noise figure measurements at the conference IS NOT to compare the results obtained to those obtained at other meetings and conferences. The goals of performing noise figure measurements at the conference are:

1) Determine if a preamp is working and if it meets its specifications.

2) Determine how one preamp compares to other preamps MEASURED AT THIS CONFERENCE.

3) And if time is available, re-tune a preamp to improve the noise figure.

Awards (certificates) will be given at the conference for lowest noise figure on each amateur radio band measured for HOMEBREW PREAMPS ONLY.

To learn more about noise figure measurements and the HP 8970B Noise Figure Meter, Agilent Technologies has two very good application notes. The first, Product Note 8970B/S-2, "Applications and Operation of the HP 8970B Noise Figure Meter and HP 8970S Microwave Noise Figure Measurement System". The other, Application Note 57-1, "Fundamentals of RF and Microwave Noise Figure Measurements". Both can be obtained via the Agilent Technologies Web Site (www.agilent.com).

2000 SVHFS Conference Noise Figure/Preamp Committee

Chair – Fred Runkle, K4KAZ

Co-chair – Jim Worsham, W4KXY

1999 Southeastern VHF Society Conference

Noise Figure Results

FREQ	CALL	DESCRIPTION	NF	GAIN
144 MHz.	KA0RYT	HOMEBREW #1	0.27 dB	18.78 dB
	KA0RYT	HOMEBREW #2	0.27 dB	25.40 dB
	WA8WZG	HOMEBREW	0.34 dB	24.98 dB
	KB8RQ	HOMEBREW MGF1801	0.39 dB	21.87 dB
	KB8RQ	HOMEBREW MGF1801	0.41 dB	22.09 dB
	K5JL	HOMEBREW	0.52 dB	18.02 dB
	W4ZPG	LUNAR	0.65 dB	23.35 dB
	W4LNG	DOWN EAST M/W	0.71 dB	16.73 dB
	W4ZPG	ARR	0.72 dB	22.27 dB
	W6OAL	ARA (165 Mhz)	1.13 dB	21.27 dB
	K4GSX	ARR	1.35 dB	17.24 dB
	W4WHN	LANDWEHR	1.90 dB	19.86 dB
	W4LNG	HOMEBREW	4.95 dB	12.14 dB
222 MHz.	K5JL	HOMEBREW	0.34 dB	21.84 dB
	K4SZ	LUNAR	2.23 dB	6.40 dB
432 Mhz.	KA0RYT	HOMEBREW "C"	0.25 dB	23.23 dB
	KA0RYT	HOMEBREW "B"	0.25 dB	25.21 dB
	KA0RYT	HOMEBREW "A"	0.30 dB	19.13 dB
	WA8AZG	WA5AGO PREAMP	0.31 dB	32.40 dB
	K5JL	HOMEBREW	0.36 dB	20.49 dB
	K5JL	HOMEBREW CAVITY	0.37 dB	20.38 dB
	KB8RQ	HOMEBREW MGF1302	0.43 dB	21.19 dB
	KB8RQ	HOMEBREW	0.46 dB	17.34 dB
	KB8RQ	HOMEBREW MGF1302	0.55 dB	22.54 dB
	KF4JUD	SSB	0.75 dB	19.29 dB
	WBTGG	JANEL	1.54 dB	16.18 dB
	KD4SHH	HOMEBREW	1.78 dB	18.77 dB
	AC4LS	HOMEBREW MGF1301	2.15 dB	7.17 dB
	K4GSX	M/W M TRANSVERTER	3.09 dB	31.00 dB
	WA8WZG	WA5AGO PREAMP	3.10 dB	8.44 dB
902 Mhz.	W6OAL	TRON-TECH	1.89 dB	42.77 dB
1296 Mhz.	KA0RYT	MOD KB2AH ONE STAGE	0.32 dB	20.38 dB
	KA0RYT	MOD KB2AH TWO STAGE	0.71 dB	24.85 dB
	W7QX	HOMEBREW TWO STAGE	0.84 dB	27.50 dB
	W4ZPG	DOWN EAST M/W	0.99 dB	27.00 dB
	W6OAL	W6PO DESIGN MSF1302	1.28 dB	15.62 dB

SVHFS Antenna Gain Measurement

Introduction – Update for the 2000 Conference

The goal of the SVHFS is to continue developing the capability to operate and deploy an on site, parking lot style, antenna measurement range. Current capability is for 144 MHz to 2304 MHz. Attached is the 1998 presentation discussing and explaining how the measurements are done and the issues associated with a short ground reflection range.

Reference Antennas – Update for the 2000 Conference

New antennas were secured by SVHFS for 144, 222, 432, 903, 1296, and 2304. These antennas will only be used for the SVHFS antenna range and will be crated up each year to retain their pristine condition. This will greatly enhance year to year accuracy and traceably. The chart in the 1998 presentation is updated to reflect the new antennas / gain values. Manufacturer provided gain versus frequency charts, will allow for gain checks on other than the SBB calling frequencies.

Test Equipment – Update for the 2000 Conference

The equipment used each year depends solely on what's available to borrow. Last year and again this year a spectrum analyzer with an internal sweep generator takes the place of the separate analyzer and signal source. This allows for all the equipment to be at the same end of the range for quicker test setup and the ability to do gain checks over a broader range of frequencies.

Frequently Asked Questions

Why are 50 MHz antennas not tested at the SVHFS Antenna range? As explained at the 1998 presentation a temporary parking lot range is not feasible for 6M. The required distance to the source (120 m / 393 ft) and the height above ground (24 m / 79 ft) is too great.

Why are gain results for some antennas outside the normal expected value? Some antennas that are brought to us for measurement are incorrectly assembled, of bad design, or have problems with the feed. Also in the past we have had a problem with a reference antenna, which caused about a 2 dB error for all antennas measured for that band. The new antennas will hopefully resolve this problem in the future.

Why are so few antenna Gain Award Certificates given out? The SVHFS has decided to award certificates to home brew antennas only. Home brew antennas of exceptional nature are recognized at the banquet. Gain results for all antennas are announced and posted at the conference and placed on the SVHFS Web site.

How do I participate? First indicate on your pre-registration what bands you want to bring. This is not a commitment, but aids us in the advance planning of the range's time allocation. Prepare your antennas in advance, preferably with a female N or SO-239 at the feed point. Register you and your antennas at the range early that morning. We start at 2M and work our way up the bands.

Chair - Dale Baldwin WB0QGH

SVHFS Antenna Gain Measurement

Introduction

The goal of the SVHFS was to develop the capability to operate and deploy an on site, parking lot style, antenna measurement range. The initial objective was to prepare for 144 MHz to 1296 MHz and to strive for 2304 MHz as well. The following presentation will discuss and explain how the measurements are done and the issues associated with a short ground reflection range.

Range Discussion

The ideal range is elevated to the extent that there is no reflection caused by the ground. Typically these ranges are many wavelengths in excess of the far field. Small ranges can and are usually of the ground reflection type. Geometry is worked out so that one end has the reflection point very close to the antenna. In a permanent range the reflection point can then be determined and optimized for a known value, which is added or subtracted out of the power measurements. Far field for our stated accuracy is greater than 20 λ or 20 D, where D is the aperture of the antenna. Height above ground need only be a couple of wave lengths. A dipole itself would have to be many wavelengths above the ground to escape the effects of the ground. A yagi antenna with several elements greatly reduces the effect of the ground.

Accuracy Considerations

Since the on site range will be a ground reflection type, there will be a 3db inaccuracy in the absolute gain measurement. By using a direct comparison against another antenna at the same height, distance, and approximate aperture the reflection falls out of the equation. This means that the comparison is only valid for this range set up at this location. Directive gain reduction, amplitude taper, and inductive coupling also contribute to the inaccuracy. With the selected range length of 20 λ our stated objective of 0.5 db antenna to antenna comparison accuracy should be met.

There are a number of choices for the test equipment to be employed. At the source a clean stable carrier is required at a level sufficient to be resolved by the power measurement equipment. To measure the power a thermal power meter, field strength meter, spectrum monitor, or a spectrum analyzer may be used. The difficulty with the thermal power meter and field strength meter is resolving the desired radio energy from the undesired, i.e. hand helds being keyed in the area. The difference between a spectrum monitor and an analyzer is generally monetary and accuracy. The accuracy of the spectrum monitor can be bolstered by using a precision antenuator. Using the anttenuator to return to a reference line on the display, the accuracy of the measurement then becomes that of the variable attenuator (around 0.7db per decade). Depending on the spectrum analyzer available, less than a tenth of a db scale fidelity is achievable.

Methodology

At the far end a Log periodic antenna with signal source is set up to greater than 4 meters above the ground for the 144 - 1296 bands. At the 20 λ point for each band a standard gain antenna will be erected and the spectrum analyzer will be calibrated to a reference point. The antenna to be tested is then erected in the exact manner and a delta power measurement is made. The delta is then either added or subtracted from the gain of the standard. For the 2304 to 10368 bands the range will be shorted to about 3 meters and various signal sources and standard horns make up the range at table height.

Chair - Dale Baldwin WB0QGH you may E-Mail me with your questions at wb0qgh@mindspring.com

Antenna Gain Measurement

Southeast VHF Society Conference

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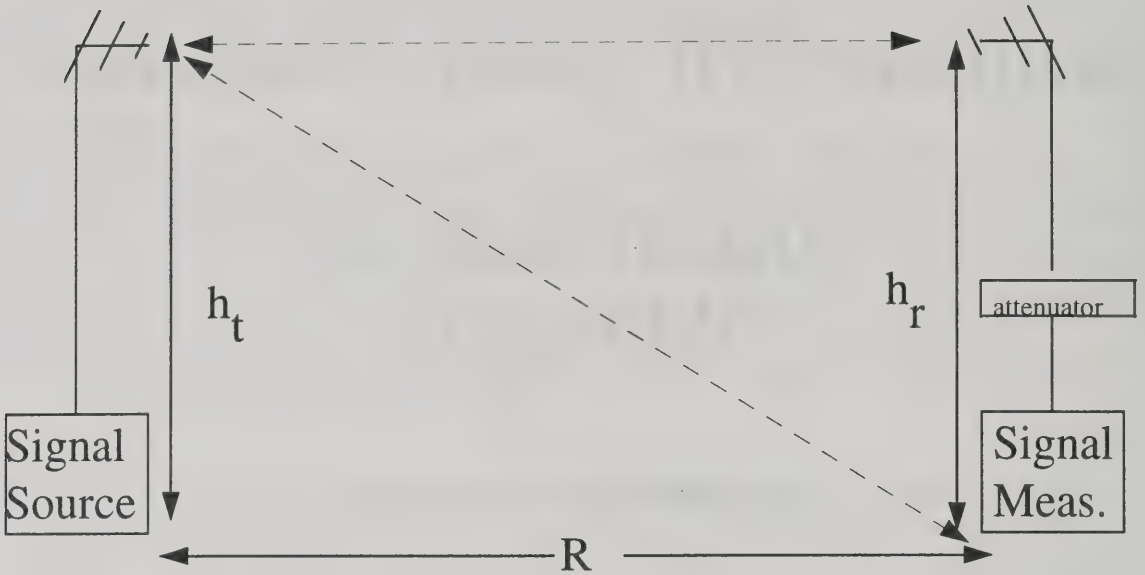
Methodology
Direct Comparison Against Standard Gain

Goals and Objectives
2M, 1.25M, 70cm, 33cm, 23cm, 13cm Bands (Actual 144Mhz-10Ghz)
Range Accuracy 1.5 ± 3 db Ground Reflection
Ant to Ant Comparison Accuracy 0.5 db
Determine Fo and Return Loss

Test Equipment
Standard Gain Antenna
RF Source
Power measurement

VHF Antenna Gain Measurement

An Elevated Range

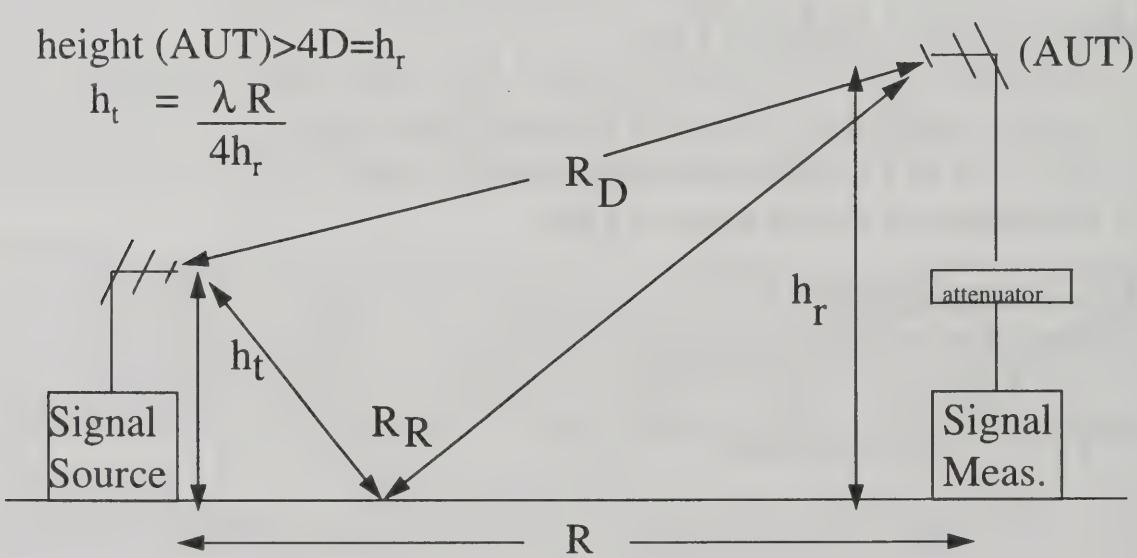


R= Far Field, aprox. 20 wavelengths

A Ground Reflection Range

height (AUT)>4D=h_r

$$h_t = \frac{\lambda R}{4h_r}$$



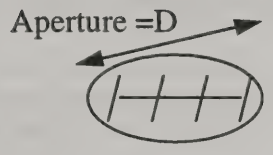
VHF S Antenna Gain Measurement

Far Field for Gain Antennas

$R_{ff} > D^2/\lambda$

$R_{ff} > 20\ \lambda$ (NF)

$R_{ff} > 20D$ (Longitudinal Taper)



Absolute Gain Measurement

$G_{aut} = 20\log(4\pi R/\lambda) - 10\log(P_o/P_r) - G_s$

Inaccuracies

Inductive Coupling	**36db**@10λ **43db** @20λ Ratio Rad to Ind
Amplitude Taper	**1db**@10D **0.5db**@20D
Directive gain reduction	**0.1**@1.5 of D^2/λ
Ground Reflection	**± 3db**@R_D μ λ/2

Methodology

Set up LP antenna with signal source, 140-1300 MHz.
Perform Return Loss measurement and Fo on Test Ant.
Set source for Fo.
Calibrate spectrum analyzer using standard gain Ant.
Put Test Ant. in it's place.
*** Use step attenuator to return to calibration point.**
*** Read new power measurement**
Delta from standard gain equals Ant. Gain.

***Alternate procedure, dependant on Test Equipment Fidelity**

VHF Antenna Gain Measurement

Antennas Used for Comparison / Standard

(Updated April 2000)

Band	Type	Gain
144	7 element yagi	10.0 dBd
222	7 element yagi	9.8 dBd
432	18 element yagi	14.3 dBd
903	19 element loop yagi	16.5 dBi
1296	25 element loop yagi	18.0 dBi
2304	45 element loop yagi	20 dBi
3456	standard horn	N/A dBi
5760	standard horn	N/A dBi
10368	standard horn	N/A dBi

Range Length

Band	20 λ Distance
144	40M 131ft
220	25M 82ft
430	14M 46ft
910	6.6M 22ft
1300	4.6M 15ft
2300	2.6M 8.5ft

SVHFS Antenna Gain Measurement

Introduction

The goal of the SVHFS was to develop the capability to operate and deploy an on site, parking lot style, antenna measurement range. The initial objective was to prepare for 144 MHz to 1296 MHz and to strive for 2304 MHz as well.

The following measurements were done with a short ground reflection range during the 1999 Conference. *Denotes homebrew award winners.

Please note: the 144 Mhz reference antenna was found damaged upon unpacking after the conference. The feed point had a couple of mechanical problems. If this happened before the measurements taken on the 9th, it helps in explaining why the gains measured were about 2 to 2.2db high. i.e. if the gain of the reference is down the antennae under test would look high.

SVHFS Antenna Measurement Results 4/9/1999

144 Mhz			
Wayne	K5YPV	11 element	11.5 dBd
Barry	WB4IZR	3 element	8.5 dBd
Barry	WB4IZR	4 element	10.4 dBd
Barry	WB4IZR	8 element	11.6 dBd
Dean	W4WHN	2 element Omni	4.9 dBd
Don	W4RDI	1 element Omni	1.6 dBd
220 Mhz			
Barry	WB4IZR	5 element	7.3 dBd
432 Mhz			
David	KD4SHH	9 element	10.4 dBd
Barry	WB4IZR	5 element	9.1 dBd
Barry	WB4IZR	5 element	8.3 dBd
Dave	WB4JGG	18 element	13.7 dBd
902 Mhz			
Dave	W6OAL	11 turn helix	7.9 dBi
1296 Mhz			
Dave	W6OAL	11 turn helix	9.7 dBd
Jerry	W7QX*	39 element	18.9 dBd
Barry	WB4IZR	1meter mesh dish	18.4 dBd
2304 Mhz			
John	W4ZPG	52 element loop	20.2 dBi

By Dale WB0QGH & Mark WB4HJG

SOME NOTES ON SHIELDING, TVI AND REVERSE TVI

RUDDY ELLIS W4LNG

I live inside the city limits of Atlanta and can see the TV towers from my house. There is a lot of garbage on the low end of both 6 and 2 meters. I set out to see what I could do to reduce this interference. I turned on my 2 meter receiver to start logging the spurious signals. This receiving set-up is shown in Fig.1. I decided to use the signal source that I described at this conference two years ago to run a quick receiving check. This test oscillator consists of a surplus computer type DIP clock oscillator and a transistor amplifier in a plastic pill bottle. The harmonic of interest happened to fall on 143.99 MHz.

While playing with the test oscillator, I turned off my preamp and was surprised; the "S" meter reading didn't change! The test oscillator was getting directly into my transceiver and its cables!. Holding the test oscillator next to the RG-8 input cable produced a strong signal. Ditto for the AC line cord, the key and T-R cables. There was some on the mike cable, but much less.

THE LEADING EDGE GHOST

I decided that my first step in cleaning up the garbage would be to greatly reduce direct signal pickup of any sort by my receiving set-up. Let's first look at coaxial cable leakage. I learned years ago, when working on TV Cable and Master Antenna systems, how leaky some coaxial cable is. Refer to Fig. 2. This is a TV set connected to a Cable or Master Ant. (CATV or MATV) system. Note that there is a leading edge ghost on the picture's left side. This ghost is caused by some TV signal being picked up directly by the TV set, a VCR or the jumper cable from the wall outlet fed by the "drop". The main signal in the CATV/MATV system is time delayed by the propagation through the trunk cable, amplifiers and splitters. The amount of the delay determines how far to the left the ghost is. This type of ghost is always a leading edge ghost, whereas ghosts caused by multipath or unterminated cable reflections can be on either edge.

CABLE TVI

The same cable leakage that causes this type of ghost will allow your Ham Radio signal to create TVI by "getting into" what is supposed to be a closed system. Look at Table 1. Cable channels 2, E, K,& WW are right in, or close to, our 50, 144, 222 & 432 Mhz bands. If you have TVI while operating on one of these bands, the first thing to do is ask the TV owner if you can come over and see how good his reception is. Hopefully, you can see some problems and can offer to help improve the reception. Check the TV owner's jumper cables connecting the set to the VCR and to the wall outlet. If they are lightweight cables, especially those with "push on" type "F" connectors, look for an opportunity to replace them with modern RG-6QS "quad" shielded cable like the cable drop from the pole should be. I have seen TV pictures, completely unwatchable due to direct pickup on a cheap jumper, that were changed to watchable just by changing the jumper.

While visiting the neighbor, you might try to explain that there is a world-wide problem with hundreds of thousands of electronic devices trying to get along with each other. Mention the military helicopter that flew too close to a powerful broadcast tower and crashed because its control electronics wasn't properly shielded for RF interference. On a more humorous note; tell the story about McDonald's Restaurants problems: When their french fry cooker heater cycled, it would cause the cash register drawer to open. When the local police bought a hamburger and took it out to the patrol car, if they keyed their police radio, the cash register gave out free hamburgers! McDonald's had so many problems that they publish their own Standards for their purchasing department to use. No more poorly shielded cash registers. No more noisy SCR controls in their oven heaters!

THE POORLY SHIELDED TV SET (or VCR)

Of course, poorly shielded TV sets will give you problems. The test for this is to disconnect the cable and see what channels you can still see. Here you must be diplomatic. You have probably heard a TV owner proclaim "look how good this set is! It has a good picture even without an antenna connected!" It is hard to convince the owner that a good (well shielded) set has NO picture without an antenna. Be carefull not to do anything that will cause the owner to blame future failures on you. You may have to bring in a TV Technician of some sort to try ferrite chokes on the line cords, long speaker leads etc. on both TV and VCR.

Another good test of shielding to perform in front of the TV owner is to tune to a cable channel which is the same as a strong local broadcast channel. The cable company usually converts the strong local signals to different cable channels, just for the reasons we have been talking about. In Atlanta, tune the TV set to channels 2,5,& 11. See if there is any crosshatching or a weak second picture in the background. If so, you can explain to the owner that he has some sort of direct signal pickup from the TV station. If his jumper is already RG-6 quad-shielded, then he either has a poorly shielded TV set, or there is leakage in the cable system. I had this problem at one time and called the cable company. A technician came out and replaced the "F" connectors on the drop from the street with modern "O"ring sealed, silicone filled, connectors (try Radio Shack 278-236 connectors). He said that corrosion in the connectors caused poor shielding and leakage. Try to help the neighbor to get his system in top condition before you even mention your Ham signals.

Of course, all of this applies to your own TV. You must have your own TV reception in order. You may have to invite the neighbor to come over and see you operate your Ham station while watching your TV at the same time. Ask Ray, WA4NJP, how he operates his kW on 6 meters with no trace of interference on channel 2. One of his secrets is to run coax cables from both underground! This attenuates the "common mode" signals on the outside of the cables, which act as long wire antennas.

TV COAXIAL CABLES

Let's review some 75 ohm TV cables you may run into:

1. RG-59/U & RG-6/U. These are the copper braided shield cables that we are most familiar with. They have good mechanical strength, but the braid does not give 100% coverage, so they will leak some. The RG-6 is a larger cable, so it has less loss.

2. The old "82 channel color TV" cable. This cable had a foil shield giving 100% coverage, but had only a single "drain" wire for strength. Avoid this type of cable.
3. Improved version of #2. This cable has 4 "drain" wires, so is a little stronger.
4. RG-6 type with single foil shield and a loosely braided shield for strength. This type works much better with the typical F-56 crimp connector, but cable companies needed something better.
5. RG-6QS type with foil shield, braid, another foil shield and another braid. Cable companies have found this cable to solve the problems of signal leakage plus mechanical strength.

Any cable is no better than its connectors. I am leary of "twist on" connectors; some are absolute junk! Refer to Fig.3. Perhaps the most important step in attaching an "F" connector to TV cables is to cut the inner foil flush with the dielectric, smooth it with your fingers, then make sure that it fits snuggly inside the connector. Make sure that the connector is the correct size. If the foil won't fit inside, the connector is too small. If the fit is sloppy, the connector is too large. This fit is important to maintain the 75 ohm impedance on up to hundreds of MHz. The crimping job is mainly for mechanical strength. Use the proper crimping tool. Avoid crushing the connector. Cables companies use hex crimp tools on the quad shielded cable connectors (try Radio Shack 278-238 or 243). Lastly, gently scrape the center conductor to remove any insulating material. End up with bright copper!

CABLE REVERSE TVI

The same leakage that allows your signal to get into the cable system will allow those cable signals, which are on Ham frequencies, to radiate and interfere with you, so if you start hearing TV signals in the Ham bands, you should look around for cable leakage and notify the cable company.

SHIELDING PROBLEMS AT W4LNG

Getting back to my situation. Look at Fig.1. I replaced the RG-8 cable with double-shielded RG-214/U. (RG214/U is the modern version of RG-9/U). Avoid all "RG-8 type" cable. Almost all of it has poor braid coverage and is very leaky. RG-213/U is the modern military version of the old RG-8/U, but is single shielded. Try vendors, such as "The Wireman", at the next hamfest for some modern cable types.

So far, we have been talking about receiving set-ups, but there are places where double-shielded coax comes in handy in transmitting systems. One good application is the cable connecting a kilowatt amplifier to an external harmonic filter. Don't let

those harmonics radiate from a leaky cable there! I lucked into a number of surplus RG-14/U cables for free and use that double-shielded cable, which is larger than the RG-8 size, for all my high power connections.

Getting back to my receiving set-up, I replaced the IEC AC line cord with a shielded IEC line cord. This gave more improvement than I expected! Both my key and T-R wires were already shielded, but leaky. I replaced the plastic covered 1/8" phone plug on the key line with a shielded plug. The multipin connector on the T-R line had a metal cover, but it wasn't connected to anything! I soldered the shield on the wire to the cover and grounded it with two small ground lugs bent over to touch the cover. Soldering here would be better but inconvenient. With all of these improvements, I can key the test oscillator anywhere around the transceiver without the "S" meter moving. Previously, I could easily get a S9+ signal.

THE COAXIAL CABLE "PIGTAIL"

Getting back to my search for garbage, my next step was to connect my WA2PZO "Poor Man's Spectrum Analyzer" to the RG-214/U cable from the antenna relay. When I built the analyzer, I used a built-in AC line filter and coax connectors on a fairly well shielded box, but it would pick up signals with no antenna connected. I had used a short piece of coax to run from the Cable tuner output connector outside the box, through a grommeted hole to the IF amplifier circuit board inside the box. I fanned out the shield, twisted it into a "pigtail" and soldered it into the PCB. Pigtails make good (bad) coupling loops to convert signals on the outside of coax cable to the inside, so they should be avoided. Always use a connector when bringing coax into a shielded box. When I replaced the pigtail with a connector, the analyzer worked properly.

I studied the analyzer display , while it was connected to my 6 meter antenna pointed at the TV towers. By watching channel 2 at the same time, I could identify major garbage at 51.67 MHz, which is the lower (vestigal) sideband of the chan.2 color sub-carrier, and 50.78, which is somehow a spur of the chan.2 audio (but distorted). Throughout the 6 meter band were carriers too weak to show up on the analyzer, but audible on the receiver. Most were spaced at 15.75 KHz, indicating TV pix. I was unable to identify any signals in the band not related to chan.2, so the only garbage removal device would be an antenna with a very sharp horizontal pattern. Has anyone tried a noise cancelling circuit or DSP on a TV sig?

Finally, I studied the analyzer display, while it was connected to my 2 meter antenna. I purposely overloaded the analyzer. What I then saw was all of the strong FM stations translated up by the chan.2 pix carrier at 55.25 MHz. FM carriers in the 89 MHz region can mix with chan. 2 in an overloaded preamp and put garbage all over the low end of 2 meters. High or band pass filters may help. A "bullet-proof" preamp is a must in an urban environment.

References:

Public Law 97-259. Gives the FCC authority to issue regulations in the area of susceptibility of "home electronic equipment and systems".

Radio Frequency Interference, How to identify and cure it. ARRL

Electrical Disturbance Standards. McDonalds Corporation

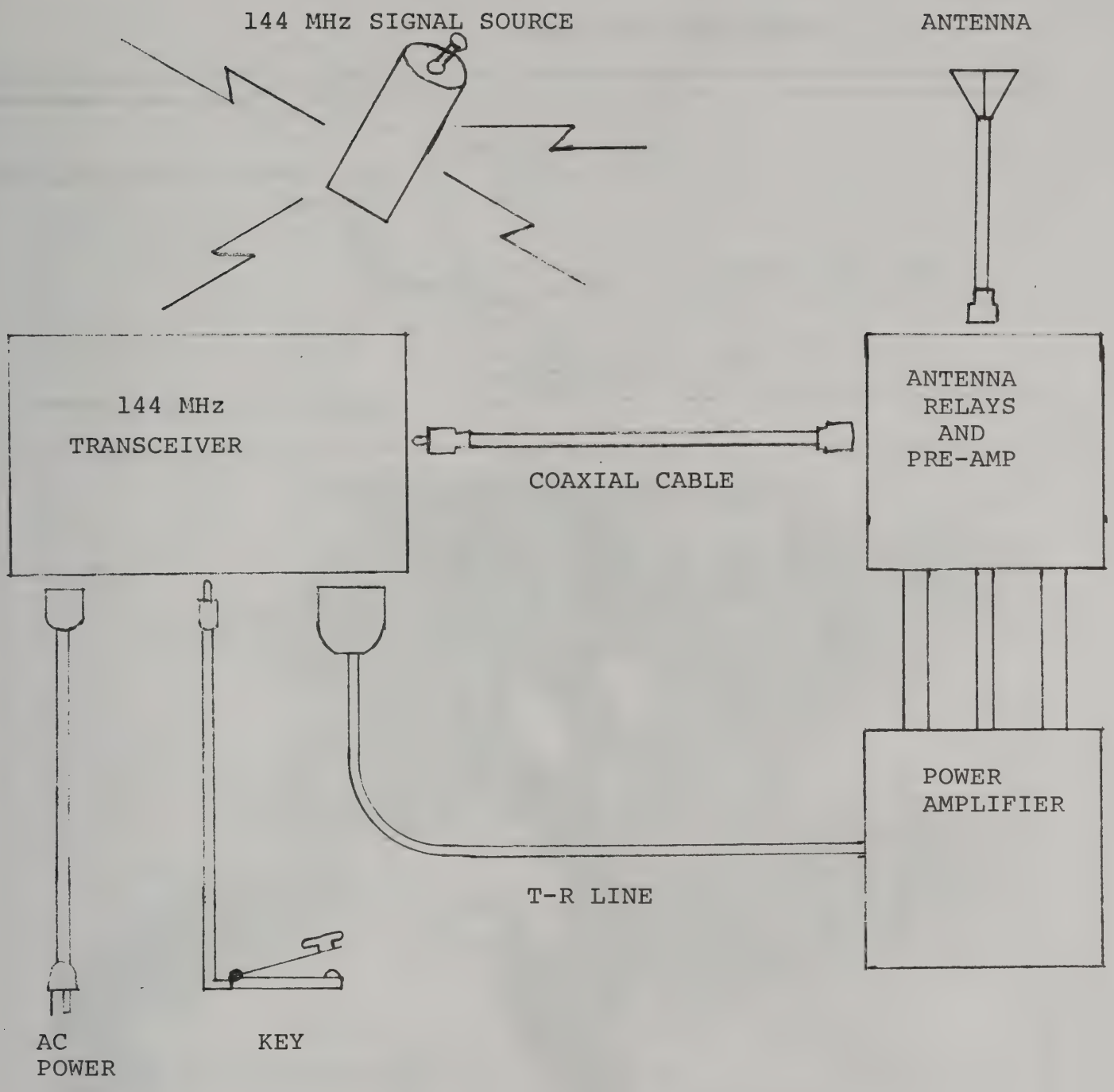


FIGURE 1. 144 MHz RECEIVING SET-UP

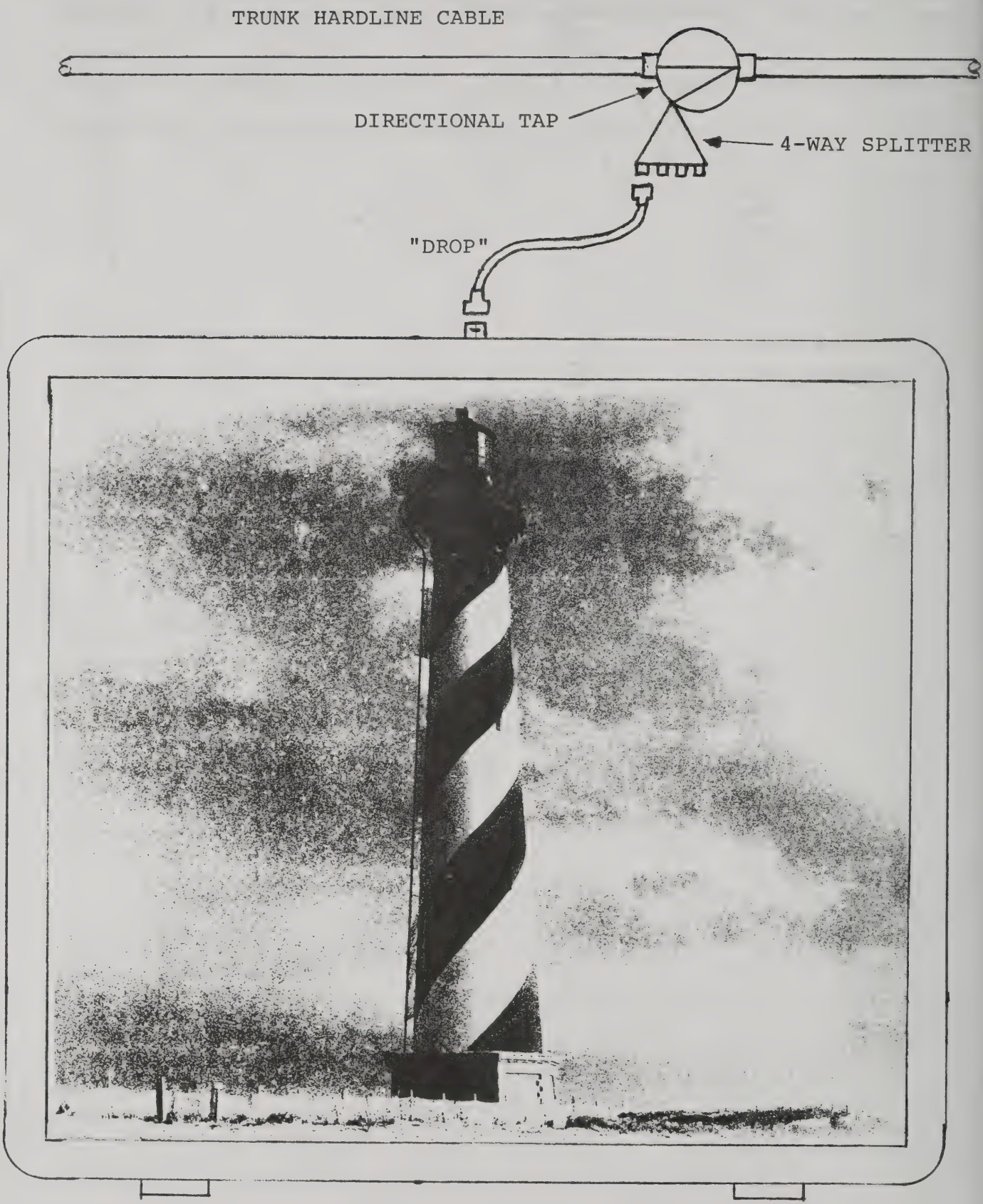


FIGURE 2. TV SET WITH LEADING EDGE GHOST

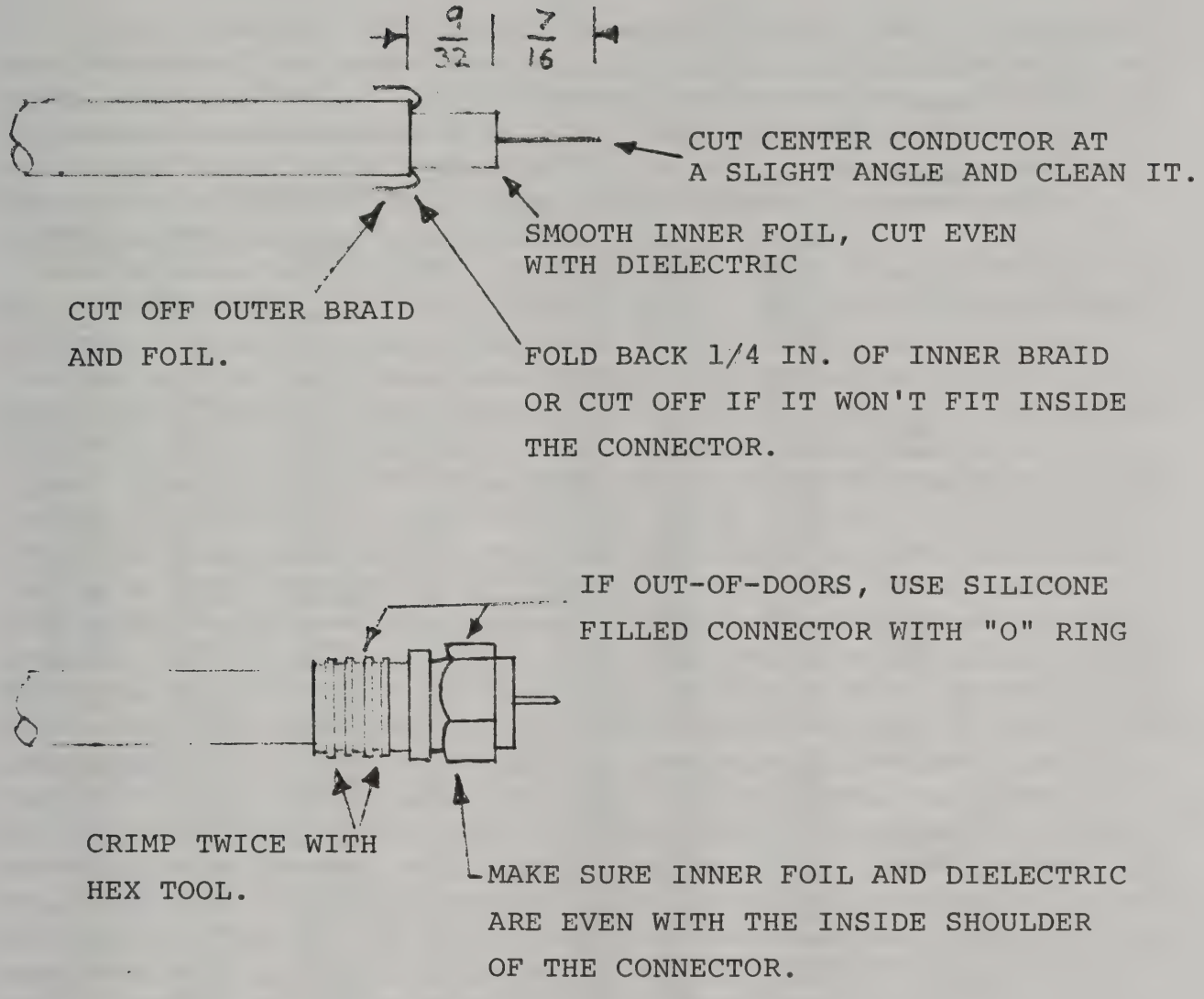


FIGURE 3. ATTACHING AN F-56 CONNECTOR TO RG-6QS CABLE

Table 1
Common Channelization Plans

Channel Name		Visual Carrier Frequency		
		Standard	*HRC*	*IRC*
2		55.25	54.0	55.25
3	Low	61.25	60.0	61.25
4	VHF	67.25	66.0	67.25
5		77.25	78.0	79.25
6		83.25	84.0	85.25
A-2		109.25	108.0	109.25
A-1		115.25	114.0	115.25
A		121.25	120.0	121.25
B	Mid	127.25	126.0	127.25
C	Band	133.25	132.0	133.25
D		139.25	138.0	139.25
E		145.25	144.0	145.25
F		151.25	150.0	151.25
G		157.25	156.0	157.25
H		163.25	162.0	163.25
I		169.25	168.0	169.25
7		175.25	174.0	175.25
8		181.25	180.0	181.25
9	High	187.25	186.0	189.25
10	VHF	193.25	192.0	193.25
11		199.25	198.0	199.25
12		205.25	204.0	205.25
13		211.25	210.0	211.25
J		217.25	216.0	217.25
K		223.25	222.0	223.25
L		229.25	228.0	229.25
M		235.25	234.0	235.25
N	Super	241.25	240.0	241.25
O	Band	247.25	246.0	247.25
P		253.25	252.0	253.25
Q		259.25	258.0	259.25
R		265.25	264.0	265.25
S		271.25	270.0	271.25
T		277.25	276.0	277.25
U		283.25	282.0	283.25
V		289.25	288.0	289.25
W		295.25	294.0	295.25
AA		301.25	300.0	301.25
BB		307.25	306.0	307.25
CC	Hyper	313.25	312.0	313.75
DD	Band	319.25	318.0	319.25
EE		325.25	324.0	325.25
.		.	.	.
.		.	.	.
.		.	.	.
UU		421.25	420	421.25
VV		427.25	426	427.25
WW		433.25	432	433.25
XX		439.25	438	439.25
YY		445.25	444	445.25
ZZ		451.25	450	451.25

Table 1
U.S. Television Channels

Channel (No.)	*Frequency (MHz)*	*Visual Carrier (MHz)*	*Aural Carrier (MHz)*
1		(Not assigned)	
2	54-60	55.25	59.75
3	60-66	61.25	65.75
4	66-72	67.25	71.75
5	76-82	77.25	81.75
6	82-88	83.25	87.75
7	174-180	175.25	179.75
8	180-186	181.25	185.75
9	186-192	187.25	191.75
10	192-198	193.25	197.75
11	198-204	199.25	203.75
12	204-210	205.25	209.75
13	210-216	211.25	215.75
14	470-476	471.25	475.75
15	476-482	477.25	481.75
16	482-488	483.25	487.75
17	488-494	489.25	493.75
18	494-500	495.25	499.75
19	500-506	501.25	505.75
20	506-512	507.25	511.75
21	512-518	513.25	517.75
22	518-524	519.25	523.75
23	524-530	525.25	529.75
24	530-536	531.25	535.75
25	536-542	537.25	541.75
26	542-548	543.25	547.75
27	548-554	549.25	553.75
28	554-560	555.25	559.75
29	560-566	561.25	565.75
30	566-572	567.25	571.75
31	572-578	573.25	577.75
32	578-584	579.25	583.75
33	584-590	585.25	589.75
34	590-596	591.25	595.75
35	596-602	597.25	601.75
36	602-608	603.25	607.75
37	608-614	609.25	613.75
38	614-620	615.25	619.75
39	620-626	621.25	625.75
40	626-632	627.25	631.75
41	632-638	633.25	637.75
42	638-644	639.25	643.75
43	644-650	645.25	649.75
44	650-656	651.25	655.75
45	656-662	657.25	661.75
46	662-668	663.25	667.75
47	668-674	669.25	673.75
48	674-680	675.25	679.75
49	680-686	681.25	685.75
50	686-692	687.25	691.75

TOWER AND ANTENNA SYSTEMS CONSTRUCTION TECHNIQUES

TOM WHITTED WA8WZG

For the weak signal vhf/uhf operator to be successful, a good reliable antenna system is a must. Many times a lot of money is spent and on a good radio, preamp, amplifier, and antenna system, but poor performance is obtained due to an inferior tower and antenna installation. The most successful operators use systems that are well thought out and constructed to insure maximum performance and safety. In this article, tower and guy wire installation, feedline considerations, rotor selection, antenna construction and installation, connector weather proofing, as well as electrical and personal safety will be discussed

First and foremost in any tower and antenna system installation is the need for personal safety. NEVER WORK ALONE WHEN ON A TOWER!!!! This cannot be emphasized enough. Always have a ground person on hand that can CLIMB (if possible) in case of an emergency. Cases have be documented where someone has gotten a finger or hand caught, and the ground person was NOT able to climb up to assist the tower worker. ALSO, you MUST BE IN GOOD PHYSICAL SHAPE before attempting to climb a tower of any height. This means exercise regularly if you plan on doing ANY tower work. Also, even if you are in good shape physically, remember to stretch your leg muscles, and do some warm up calisthenics, before you climb the tower. This will prevent any cramping and muscle pulls. Also, you must be in the right frame of mind and be focused on the task at hand. If you are not concentrating 100% on what task you about to complete, then it will be very easy for you to make a mistake and a serious accident or damage to your equipment might take place. Personal safety equipment is a necessity for tower and antenna work. NEVER USE A ROPE TIED AROUND YOUR WAIST in place of a good climbing belt. A good quality climbing belt and safety strap can be obtained for under $100 from many companies, one of which in ONV safety belt company, which advertises in most of the Amateur radio magazines. Many times you will find USED safety belts made of leather at the local swap meets. These are throw aways from utility companies. The reason they are thrown away is the fact that they are out of the manufactures safety date code, and NOT reliable. Think about it would you risk your life for a few dollar savings!!!!! Also, many times one will borrow a belt from a friend, and if you do, take the time to inspect the belt completely for any nicks in the safety strap, or fraying of any of the material. And MAKE SURE IT FITS properly!!! You will not be able to use it safely if you are a size 32 waist and your friend is a size 40!!!
Ok, a lot of space was used to discuss safety. But, it is the MOST important part of any amateur radio system so PLEASE think and work safe.

Now that we have all of the safety gear we need, the tower construction can begin. The first step is to locate the proper site for the tower. Again keep in mind that you are building a WEAK SIGNAL VHF/UHF station, and practices that work on the low bands DO NOT WORK for weak signal. You want to keep the tower as close as possible to the radio operating position. The feed line losses on the weak signal bands, with the possible exception of 6 meters, will degrade the performance of the station tremendously. Also, make sure that the position of the tower site is far enough away from any electrical lines or utility lines in case of a disaster that would cause the tower to fall and become tangled in the utility lines. Finally if the tower is to be higher than 30 feet it must be guyed unless of course it is a self-supporting tower. If a self-supporting tower is to be used, make sure that YOU DO NOT exceed the manufactures listed

wind rating. The weak signal operator usually has multiple antennas stacked on the top of the tower and these added forces must be considered when the total bending moment is calculated and the proper tower is selected. If you use a guyed tower such as the popular Rohn 25 and 45 series of towers, then pick a suitable site for your tower so that the guy wires can be anchored as close to an even 120 degree separation as possible. Also, make sure that you will be able to have the proper distance from the tower to the guy anchor that is need for the height of the tower. If you unsure of how to make these calculations then please contact ROHN tower company at 6718 West Plank Road, Peoria, Illinois 61656. Their catalog has all the nessesary information that you will need to calculate guy wire spacing, anchor distance from tower, and base construction.

Now that the site has been selected, dig the hole to the proper size recommended in the Rohn specifications. Do not make the base to small to save some time and money and do not forget to put at least 4 inches of loose stone in the bottom of the base. The tower MUST set on a solid object to hold the bottom of the legs in the stone when the concrete is poured. This is to insure that water that gets inside the tower legs can run out the bottom freely. If you do not adhere to this and you live in an area that gets temperatures that go below freezing, then the water trapped inside the tower will freeze and cause the tower to split, see picture A at the end of this article.

Now that the tower base is poured and cured, the erection process can begin. Again with safety in mind all tower workers should have a hard hat on!!! A small 3/8 nut dropped from 60 feet can cause serious injury if it hits a person on the top of the head. The next step is to assemble the tower sections on top of an another one section at a time using a gin pole. If you do not have one they can be made easily using information in the ARRL handbook, or they can be obtained from Texas Towers or IIX equipment in Illinois. Both these suppliers advertise in QST magazine as well as others. As the tower sections are hauled up by the ground crew and started to be set into place, many times it will be noticed that the sections will not align themselves properly. This is especially true of used tower. There is NO way that they can be bent by hand into place on the tower, to make them align, but there are two specialty tools on the market that are not very expensive, and that can aid in the process of aligning the sections into place. These tools are called the "Tower Jack" and the "Tower Aligner" and again are avaiable from the manufacturer or their dealers located in the various Amateur Radio magazines. One important side note here is that DO NOT ATTEMPT to assemble the tower on the ground and then lift it into place by "walking" it up. The weight that is exerted down is more than can be handled safely by the ground crew.

Once the tower is up to the height for the first set of guy wires, then the guy wires should be attached to the tower and anchors properly. First use a quality EHS guy wire, NOT ROPE or coated clothesline!!! Attach the guy wire to the tower using 3/16 or 1/4 cable clamps. These can be obtained at the local hardwire, and make sure that they are the galvanized type. Next, attach the guy wire to your anchor system using a **quality** turnbuckle. Use the galvanized steel, not the aluminum type. See Picture B at the end of the article for details. One side note here is on the proper type of anchor system. Use an anchor screw that is rated for the type of soil that you have. A good source for these is the local hardware in you area or the Builders Square or large type of home improvement store. If you live in a rocky area then you might want to consider a pipe concreted in the ground, type of arrangement Also, when installing the screw type of anchor, screw it in the ground at the same angle as your guy wire will attach. DO NOT screw it straight down into the ground. This will cause the anchor to be pulled toward through the ground toward the tower and result in the guy wire becoming loose over a period of time.

Ok, now the tower is up and guyed and you are ready to install the antennas that you have built. Before hauling up the first antenna, make sure that the SWR (return loss) has been checked with the antenna at least 10 feet above the ground and away from any object, or building that might affect the tuning. Also, a good recommendation is to spray the entire antenna with Krylon spray clear coat to keep corrosion down. Make sure that the antenna is tuned and all connections on the matching system are secured in their final place before the antenna is coated. Also, this is a good time to make sure that the antenna mast pipe clamp will fit your mast pipe. Many antennas for 903 and above use 1-1/2 inch mounting saddles, and it will not be fun to find out at 100 feet that the antenna will not fit on the 2 inch mast!!!.

Now that the antennas are assembled properly, the task of hauling them up the tower and through the guy wires begins. Again use the gin pole and a tag line tied on the boom of the antenna at the opposite end of the antenna from where the pull up rope is attached. This tag line can be used by the ground crew to guide and steer the antenna away from the tower and guy wires. MAKE SURE that the tag line is tied close enough to the mast clamp on the antenna so that the rope can be reached easily and untied. If it is tied to close to the end of the antenna, then it will not be able to be reached from the top of the tower to be untied, and a few choice words will be had from the person on top of the tower!!! After the antenna is mounted, then install the feedline rotor loop. It IS VERY important that you water proof this connection carefully. In most cases you will not be able to reach it to repair it once the mast pipe has been pushed up. A good recommendation is to use the Butyl rubber that is avaiable from electrical supply houses or from Andrew Company. It comes in 4-inch widths and is very easy to use to form around the connections and makes a very waterproof installation. Before apply the sealer, wrap the connection tightly with black electrical tape, this will allow the sealer to be removed from the connection if ever repairs to the antenna are needed.

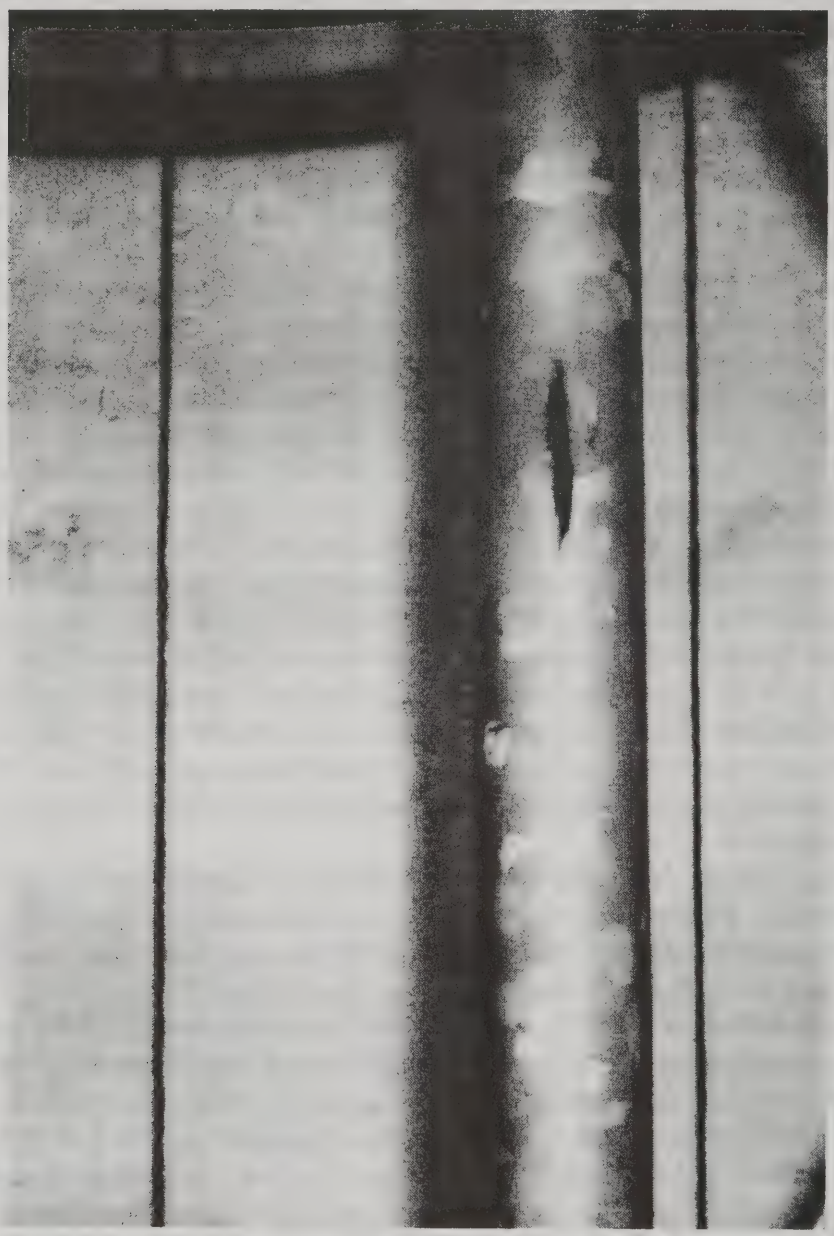
Continue to install the rest of the antennas, as above and when the final antenna is in place, then it is time to install the rotor. Make sure that the rotor will fit in the tower and rotor shelf, before it is hauled up the tower. After installing the rotor, lower the mast into the rotor and turn the whole array by hand with a pipe wrench to make sure that the rotor is centered properly and that nothing is binding in the thrust bearing or top section of tower, which ever is the case. A good recommendation here is NOT TO USE the standard "cone style" top sections. With a long mast pipe and close tolerances in the neck of the tower, a binding problem can develop when trying to turn the antennas in the wind. A better solution is to use the flat plate top section and a thrust bearing arrangement.

If there is no binding, then tighten the mast pipe in the rotor after aligning the antenna for the proper direction with the rotor control. Make sure that some time is spent doing this as if the antennas are not aligned properly and they are 4 to 5 wavelengths long, they will be VERY directional and aiming problems will result.

Finally, make a rotor loop of at least 6 to 8 feet depending on the quantity and type of feed lines that were used to go around the top of the tower. There should be NO binding, rubbing or catching of the feedlines on any portion of the tower.

Attach the rotor loop feedlines to the feedline going down the tower, if that is the setup that is being used, water proof the connections well and then tape the feed lines to the tower ever 3 to 5 feet. When you use the tape, do not pull it hard and allow it to tear, or “break”, itself off. This causes the tape to stretch and then it will pull back to its original length over a period of time and it will not stick properly any more. If you are using Heliax cable, then tape will not hold the weight properly, and the use of stainless steel hose clamps MUST be used.

As the cables are brought down the tower and into the shack, make sure that a drip loop is left outside the wall to keep water form coming into the shack. At this point you are ready to attach the feedlines to the radios and enjoy the world of weak signal work, knowing that your antenna and tower system is installed properly and will give you many years of trouble free enjoyment. A final note as with any construction project, make sure that you apply for any local permits that are needed and that you stay with in any local zoning codes. If you have any questions, please feel free to contact me via e-mail at WA8WZG@WA8WZG.COM . 73's and good DX to you.



EXIBIT A

EXIBIT B

DIRECTIONAL COUPLERS
and
THEIR USE in AMATEUR RADIO

Bruce Randall WD4JQV

WHAT IS A DIRECTIONAL COUPLER?

From.... IEEE Standard dictionary of electrical and electronic terms:

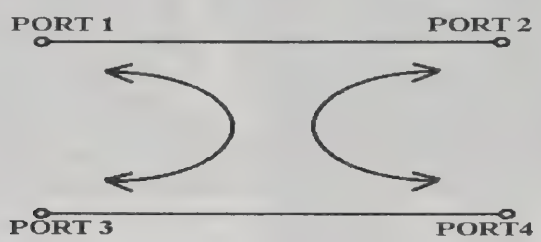
DIRECTIONAL COUPLER (1) (Transmission Lines.)

A transmission coupling device for separately (ideally) sampling (through a known coupling loss for measurement purposes) either the forward (incident) or the backwards (reflected) wave in a transmission line. Notes: (A) Similarly, it may be used to excite in the transmission line either a forward or reflected wave. (B) A unidirectional coupler has available terminals or connections for sampling only in one direction of transmission; a bidirectional coupler has available terminals for sampling both directions.

WOW! What a mouthful of words!

There are several symbols used for directional couplers. I prefer the one below

DIRECTIONAL COUPLER SYMBOL

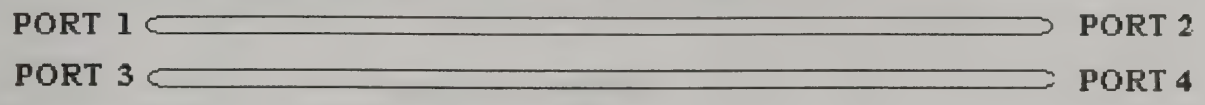


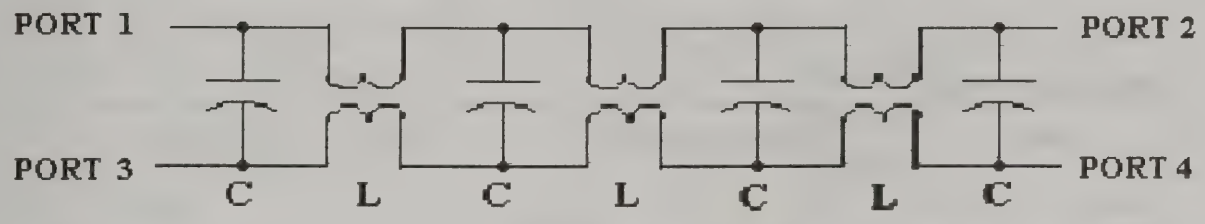
- A wave from port 1 to port 2 will also show up in port 3 reduced by the coupling ratio, but not in port 4. The same pattern applies to any combination of ports.
- Note that the curved arrows represent the directions that a coupled signal goes across the coupler.
- Note that the position of the ports on the symbol correspond to the actual position of the port on a transmission line coupler. This is NOT true of waveguide or transformer type couplers!

Most amateur VHF and microwave applications will use transmission line couplers.

TRANSMISSION LINE DIRECTIONAL COUPLER

- TWO PARALLEL TRANSMISSION LINES SHARE THE SAME ELECTRIC AND MAGNETIC FIELDS





Power Flowing from port 1 to port 2 will couple some power into the port 3 to port 4 line. Because of the phase relationship between the inductive and capacitive coupling the signals at port 3 add together resulting in an output. The two coupling mechanisms, however, cancel at port 4 resulting in no output. Any of the incident power that is reflected at port 2 will cause an output at port 4.

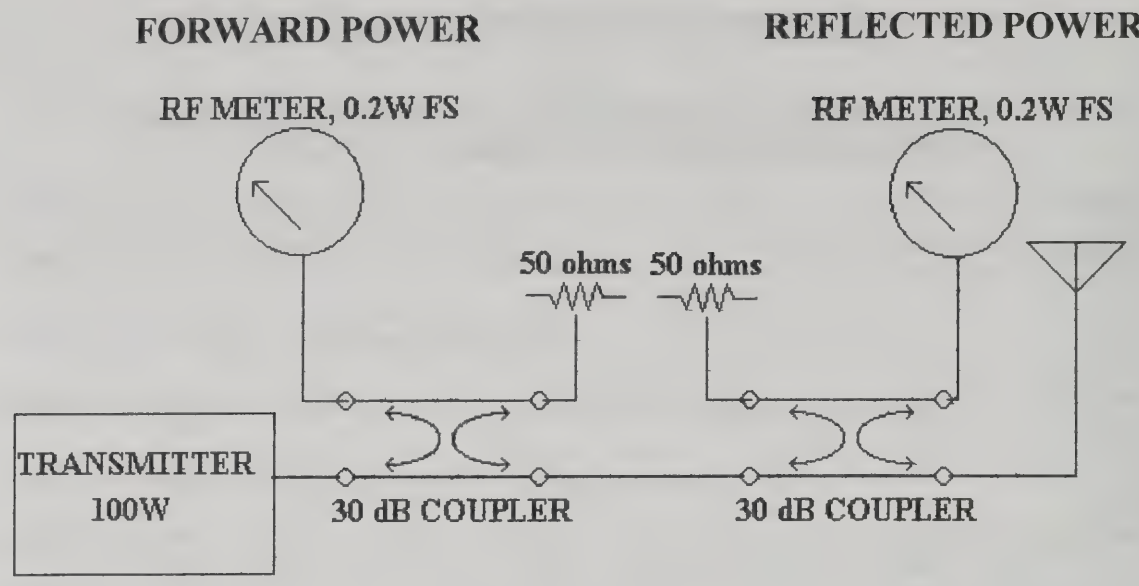
- The coupling changes with frequency. This type coupler give relatively constant output over a one octave range. This range is centered on the frequency where the coupled portion of the lines is 1/4 wavelength long. (Include velocity factor!)
- The maximum usable frequency is 1.7 x the center frequency. At 2 times the center frequency there is no coupling!
- Below the center frequency this coupler is still useful. The coupling falls off at 6dB per octave as the frequency is lowered below about 1/2 the center frequency.
- This type coupler can be made very low loss, so it can potentially handle large power levels.

Directional Coupler Applications:

- Transmitter power measurement, forward and reflected.
- Low level return loss measurements on antennas.
- Preamp input and output return loss measurements.
- Insertion of receiver test signal into antenna line
- IF signal sampling.

Transmitter power measurement

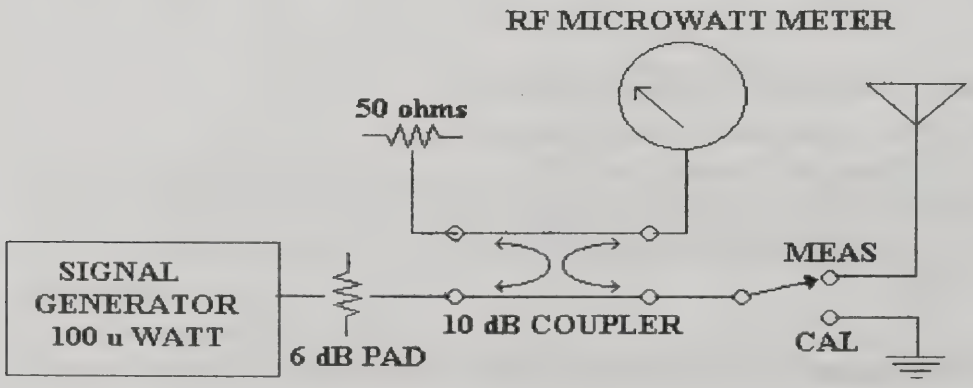
Directional couplers sample the forward and reflected power from the transmitter and antenna. These samples are measured and used to compute power and return loss. Return loss is another way to describe SWR.



Notes:

- Termination resistors on the coupler must be accurate 50 ohm loads. Many couplers have the termination resistors built in. An ohmmeter on the coupled output port will read 50 ohms if the termination is built in.
- ***Don't smoke the terminations.*** Transmitter power divided by coupling ratio should be well under 1/2 watt. **This applies to both forward and reflected couplers!**
- 1500 Watt transmittters need 36dB + coupling for the coupler terminations to survive!
- A high SWR can result in 2 times the expected power in the terminations.

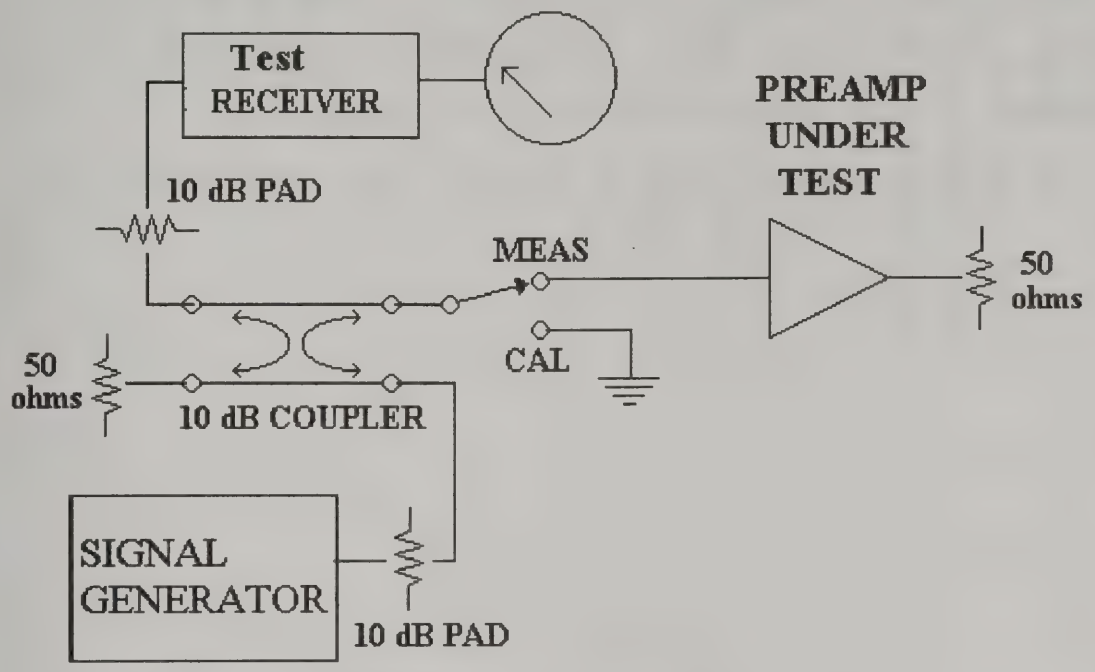
Low Level Return Loss Measurements



This is the safe way to adjust an antenna for low SWR. With under a mW on the antenna it is safe to adjust live. The dB difference between meas. and cal. is the return loss of the antenna.

- The 6 dB pad on the generator output is needed to avoid mismatch errors.
- This setup often uses a modulated signal generator. A square law diode detector with a HP415 or similar device is used for the power meter. The 415 is marked as being a SWR meter, but is really an audio voltmeter with special scales for the application.
- Strong signal received by the antenna can cause erratic results.

Preamp Return Loss Measurement



- Note the different connections of the directional coupler compared to the antenna measurements. This is needed to keep the signals as small as possible at the preamp input.
- If the preamp is over driven the results will be wrong. Lower the signal generator level by 2 or 3 dB and verify the results don't change.
- By reversing the input and output connections on the preamp the output return loss can be measured.

References:

1. Brian Bwewster, "A Coupled Microstrip Line Review and Design program", RF design , December 1993, pp. 58-64.

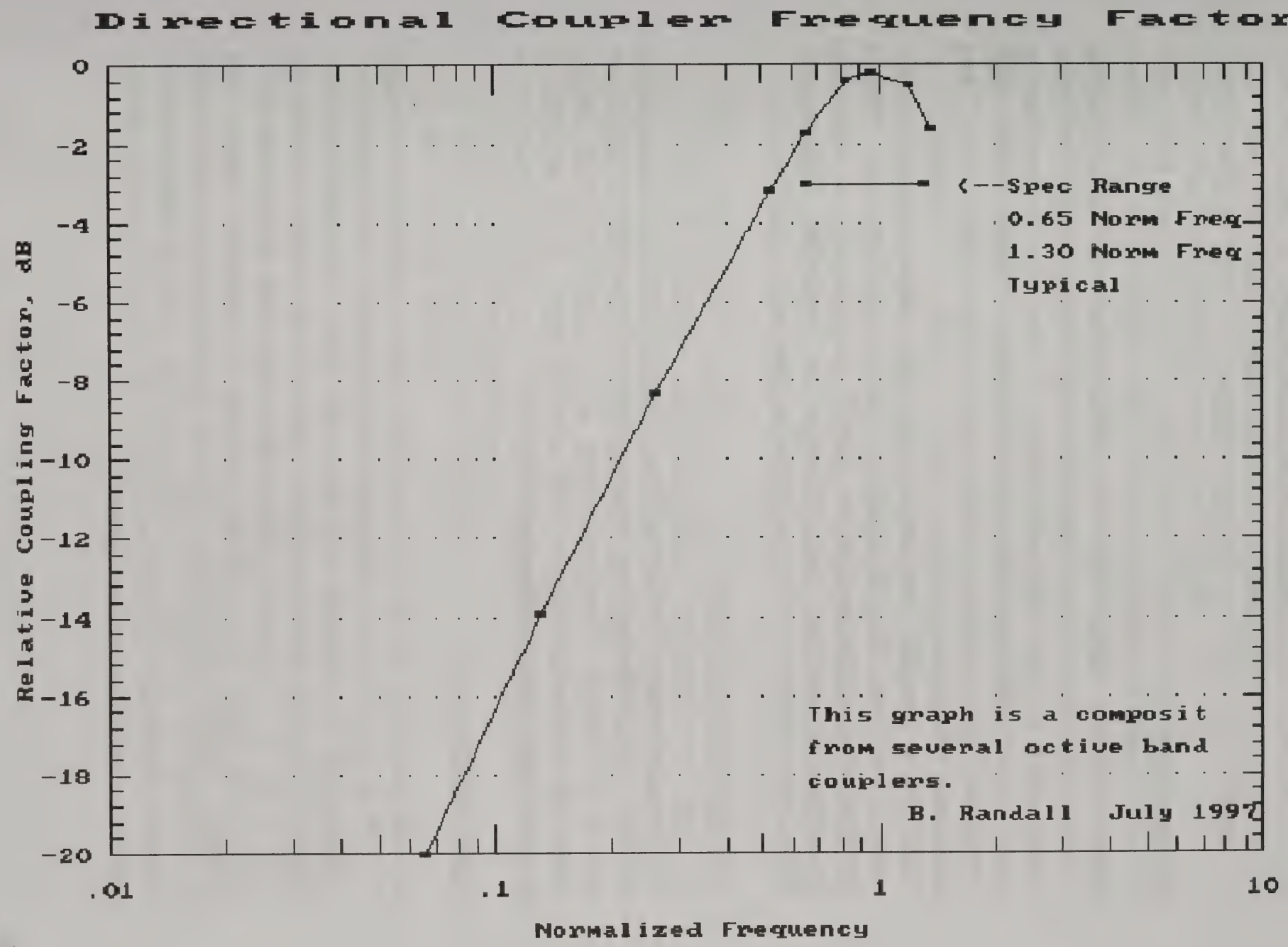
2. Michael G. Ellis, Ph.D., "RF Directional Couplers", RF design, February 1997, pp. 30-44.

3. Charles E. Smith, Mark D. Tew, and Wen-Liang Wu, "Use SPICE to Analyze PCB Crosstalk", EMC Test & Design, April 1994, pp. 20-27.

4. RF/IF Designer's Handbook,1992/1993,Section 7, Mini-Circuits Labs, P.O. Box 350166, Brooklyn, New York 11235-0003. (Supplier of transformer type directional couplers. Also has good applications information.)

5. Wes Haywood, W7ZOI, Introduction to Radio Frequency Design, The American Radio Relay League, 225 Main St., Newington, Ct 06111-1494, pp. 151-159. (Good general reference on all aspects of radio equipment.)

6. Bob Stein, W6NBI, "How to Use the SWR Indicator", ham radio, January 1977, pp. 66-71.


Directional Coupler Frequency Factor
Relative Coupling Factor, dB
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
.01
.1
1
10
Normalized Frequency
<--Spec Range
0.65 Norm Freq
1.30 Norm Freq
Typical
This graph is a composit
from several octive band
couplers.
B. Randall July 1997

Application notes on adding
low-level ALC to transverter out line
on TS-850

The problem

Many of us use various HF rigs to drive our favorite transverters on vhf and uhf. Most of these rigs have some sort of provision for a low-level output to drive the transverters, or, they can be modified to provide one. This note deals with the Kenwood TS-850, but the data can most likely be applied to other rigs which have low-level ALC and some way to access it.
When using the 850 transverter output per the instructions in the manual, the power amp is disabled.....but..... so is the ALC. This is not good, since now the variable gain IF stage can go to maximum gain, causing a serious degradation of the transmitted SSB signal. Third-order distortion products can be as poor as –15db!!

One of the possible cures

It is possible to amplify the transverter out signal to feed back to the 850 ALC circuit, fooling the radio into thinking that the PA is still on line. A DC voltage of approximately -8.5 is required at full output. Since the transverter output is milliwatts, not watts, a DC amplifier is required to increase the feedback signal.

Theory of operation

A small sample of RF is "borrowed" from the transverter line through C1 and is converted to a DC voltage by D1 and C2. U1 amplifies this voltage, with the ultimate gain set by R4. D2 is used to isolate the output of U1 so it can be paralleled with existing circuitry. It would be wise to use a 10-turn pot for R4 to allow for easier adjustment. A TI TLC272 is used at U1 simply because it requires a single Vcc voltage. I found it necessary to change the original value for C2 from 0.1 to 0.001mf to keep the time constant short on charging C2. Originally, there was an obvious "spike" that took some time to decay; it is absent with the smaller capacitor.

You will need to decide which way to obtain your low-level output from the 850. The standard way is simply to move one of the minicoaxes on the RF board from CN2 to CN25 and follow the instructions in the manual for the bias TEE etc.
The other way, my way, is more radical since it involves removal of the PA stage so that you can build the transverter into the 850. In this case, you don't move any cables on the RF board, you just use the one that normally goes to the PA module.

Once the board is completed, here's what you need to do:

- You need to be able to get to the bottom of the RF board, so remove its chassis hold-down screws and enough of the ribbon and other cabling to carefully invert the board for soldering.
- Solder a 12" piece of RG174 (or equivalent) on bottom of RF board to CN25 "land", or, connect to the coax that goes to the PA module; leave other end unterminated.

- Still on bottom of RF board.....
  It would be good to use small, teflon insulated wire (like #24 stranded), and to use different colors for the 3 connections.
  a) solder 12" piece of hook-up wire to pin 1 of CN16
  b) " " " " " " 3 "
  c) " " " " " " 6 "
- Connect the wiring to the ALC dc amplifier board; (you have to decide where to mount the board).
  a) The coax goes to C1 and ground
  b) Pin 1 goes to ground
  c) Pin 3 goes to +14
  d) Pin 6 goes to the cathode of D2 (vsf)
- If you have an "intact" 850, tune it to 28100; put in FM mode; connect dummy load to output and key the mic; then adjust carrier level for a mid-scale reading on the ALC meter.
- Connect the IF port through an RCA cable to +8 to +12VDC and key the mic again. Adjust R4 for the same mid-scale reading on the ALC meter.

- Check transverter output level and adjust carrier level for 10mw output; the output signal should be very clean at this level, particularly with the ALC back on line. Measurements indicate 3rd order distortion products of –32db or so, which is very respectable.

This modification was originally thunk up by Dave Dabell, WA3U, and was published in Cheesebits, a Packrats publication. All I have done is continue a dialog with Dave, get some PC boards made and modify the circuit a little. Boards are available from Fred at FAR Circuits.

To cleaner signals.....
73

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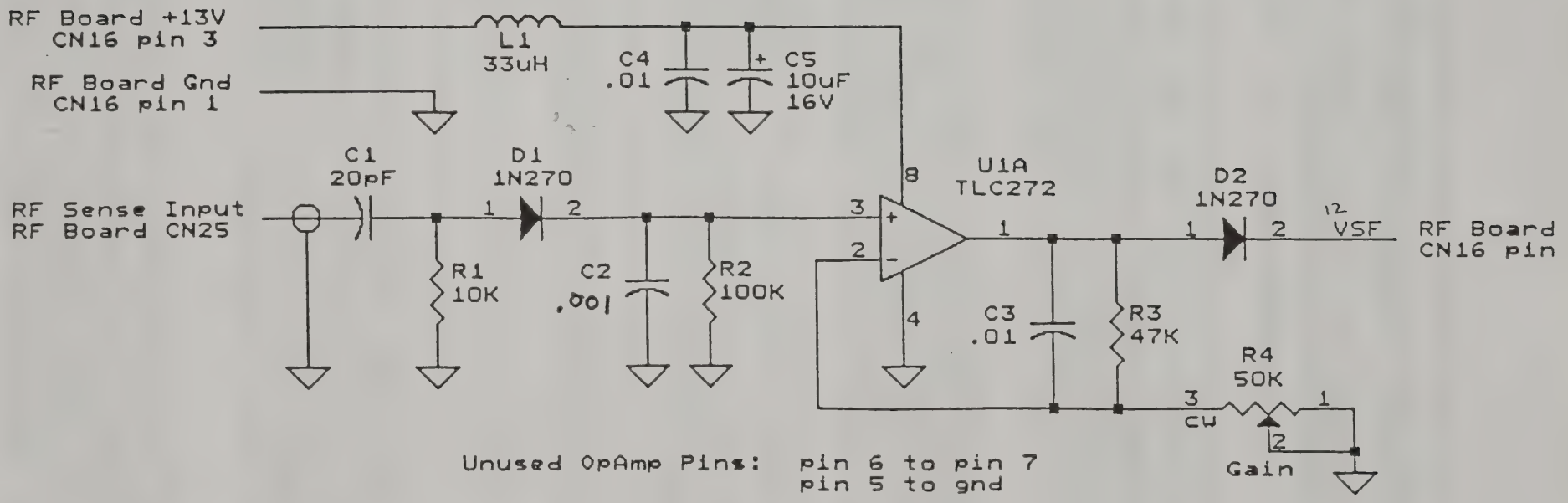
RF Board +13V
CN16 pin 3
RF Board Gnd
CN16 pin 1
L1
33uH
C4
.01
C5
10uF
16V
C1
20pF
D1
1N270
RF Sense Input
RF Board CN25
R1
10K
C2
.001
R2
100K
U1A
TLC272
8
3
2
4
1
C3
.01
R3
47K
D2
1N270
12
VSF
RF Board
CN16 pin
R4
50K
3
CW
1
2
Gain
Unused OpAmp Pins: pin 6 to pin 7
pin 5 to gnd

A Single-Board Transverter for 10 GHz

Paul Wade, W1GHZ ©1999
wade@tiac.net

Introduction

The ARRL 10 GHz cumulative contest has spawned a lot of interest in 10 GHz operation. In last year's contest there were over 40 stations active in New England alone, with many others having an interest but no equipment to enable them to participate. In other VHF contests, 10 GHz is the second most active band above 432 MHz — only 1296 MHz sees more activity.

Many of us started on 10 GHz with simple wideband FM transceivers[1]. Some of these were as simple[2] as a converted police radar detector or supermarket door-opener, with a modified FM broadcast receiver as an IF radio. WBFM operation is fun and capable of impressive distances, over 200 km for a clear path, with quite basic equipment and simple horn antennas.

For real DX, narrowband modes of operation are needed — usually SSB and CW. Just narrowing the receive bandwidth from 200 KHz for WBFM to hundreds of Hertz for CW provides roughly 30 dB improvement, and equipment improvements can provide further increases. By the inverse-square law, doubling the path length requires 6 dB more signal, so 30+ dB is a major increase in capability.

The missing piece needed for affordable 10 GHz narrowband operation is a transverter which can be readily reproduced. The goal of this single-board transverter design is to provide reproducibly good performance.

Background

A simple WBFM transceiver relies on a Gunn-diode oscillator to provide all the microwave magic. Narrowband equipment is much more complex, usually a transverter from some lower band. The narrow bandwidth requires a very stable oscillator, and linear amplification is needed for SSB operation. Amplification at microwave frequencies has historically been difficult and expensive, but improvements in semiconductor technology have helped significantly in recent years.

The most useful semiconductor device is the microwave GaAsFET. Although intended mainly for low-noise amplifiers, hams discovered that they could be pushed to provide modest amounts of power. In 1993, I built a 10 GHz transverter[3] using a number of modular building blocks containing GaAsFets. Each of the modules was hand-built and hand-tuned, but a number of hams have used copies of some of the modules as well as surplus components to assemble

working transverters. Around the same time, KH6CP[4] (now W1VT) and G3WDG[5] in England each described a modular transverter.

The only commercial equipment for the 10 GHz band comes from Germany. The initial cost seems quite high, but I'm sure that many of us spent a good deal more on parts and test equipment before we had a working system.

At the lower microwave frequencies, single-board "no-tune" transverters are very popular. They provide good performance at low cost, using MMIC amplifiers and stripline filters printed on the circuit board. Above about 4 GHz, printed filters are hard to make consistently due to tolerances in both dimensions and dielectric constant. They also suffer from radiation as the board thickness becomes a significant fraction of a wavelength — and making the board thinner only makes the tolerance problem worse.

In 1997, I described a single–board transverter for 5760 MHz[6] which uses tuned filters made from common copper plumbing pipe-caps. Similar filters[7] were used in the modular 10 GHz designs cited above, but the modular construction allowed individual tuning. Although the 5760 MHz single-board unit uses five tuned filters, the tuning procedure is simple and straightforward, demonstrating that a no-tune design is not necessary — hams are capable of tuning.

Design Considerations

The success of the 5760 MHz single-board transverter design brought a frequent question: "What about a 10 GHz version?" However, there were still several problems to solve for a design that can be reproduced in quantity, without requiring an undue amount of expertise:

1. Grounding: without excellent grounding, gain and stability of the MMIC amplifiers is degraded.
2. Radiation from the microstrip transmission lines becomes significant at higher frequencies, resulting in losses and unwanted coupling.
3. The pipe-cap filters have more loss at 10 GHz.
4. Filtering for the popular 144 MHz IF is more difficult at 10 GHz.
5. The transverter circuit board is large enough to flex during handling, resulting in cracked solder joints on some of the surface-mount resistors.
6. The LO multiplication factor is too large for a single frequency multiplier. Experience suggests that the frequency multiplication from 568 MHz to 10 GHz would work better if done in two steps.

As a first step, I cut out the LO multiplier section from a 5760 transverter board and assembled it with ½" pipecaps rather than the normal ¾" ones. NØUGH[8] had reported good results at 10 GHz from a X3 frequency multiplier using an ERA-3 MMIC, so I tested the assembly with a X3 frequency multiplication ratio. The output power at 10.224 GHz was more than adequate for a dual mixer, solving one problem: inadequate LO power to the mixer, a weakness in many microwave designs.

Now I needed a way to get from 568 MHz to 3408 MHz to drive the X3 multiplier. I was confident that another MMIC frequency multiplier would do the job, but a compact filter at 3408 MHz was still a problem, since a 1" pipecap would be too high for the aluminum enclosure used for the 5760 MHz transverter. N2CEI tried longer screws in the ¾" pipecap filters and found that they could be tuned low enough in frequency, completing the solution to problem number 6 above.

Problems 3 and 4 are solved together: add an additional pipecap filter in both transmit and receive chains for filtering, and an additional MMIC stage in each chain to compensate for the losses of all the filters. The trick is that separating the filters with an amplifier stage makes the tuning of each filter independent from its neighbors, and the loss of the filters isolates the amplifier stages from each other, improving stability of the amplifiers. KK7B once explained to me that this is the secret that makes no-tune transverters possible.

However, some of the isolation is lost if there is significant radiation from the transmission lines. Most of us have built preamps that work well until we put a cover on the box!

Problems 1 and 2 are made more difficult by the desire for reproducibility. As an example, AF1T and K2CBA have each made a single-board 10 GHz transverter with similarities to this one. Each had transmission lines cut out by hand with a hobby knife, and good grounding was accomplished by carefully bending the MMIC leads and fitting them into small slots cut in the board. Radiation was controlled by adding shielding strips soldered vertically to the board. The process is tedious and painstaking, performed by skilled and experienced microwavers, so the end result works well.

The reproducible alternative calls for a professionally made printed-circuit board with plated-thru holes for grounding. In the past, Down East Microwave[9] has produced affordable kits for hams based on some of my articles, so this time I approached Steve before starting the design so that he could help make it reproducible. For instance, the best way to reduce radiation from the microstrip lines is to make the dielectric thinner. Steve confirmed that his PC board supplier could supply very thin Teflon boards with adequate line tolerance, so we chose a 0.015 inch board thickness, half as thick as the previous 5760 MHz design, to control radiation.

An additional advantage to the thin board is that the length of the plated-thru ground holes is also halved, so that the ground inductance is also cut in half. Problems 1 and 2 are solved together. The disadvantage of the thin board is that it is much more difficult to produce a prototype in the basement — we chose to have a small lot made professionally, knowing that we would find small problems and end up discarding them.

The real disadvantage of the thin Telfon board is that it is *very* flexible. When I built the first prototype, shown in Figures 1 and 2, I added several stiffeners of brass angle stock. Even so, one of the solder joints for a chip resistor cracked during tuneup, making the output intermittent. A better solution to problem 5 was needed. Steve and I discussed several possibilities; one we considered was backing up the thin Teflon board with a much thicker backup printed circuit board of conventional fiberglass material. Finally, Steve came up with an elegant solution: a

mounting plate of thick aluminum with cutouts for the pipecaps that also serve to align them during soldering. The aluminum is thick enough to allow threaded holes for connector mounting as well. The aluminum mounting plate would take me hours to machine but modern CNC machinery apparently works a lot faster and cheaper than I do!

Prototype Description

Once the problems were worked out, we could start the actual design. The schematic diagram, shown in Figure 3, is an extension of the 5760 MHz single-board transverter. The LO section is split into two frequency multiplier sections, and both the transmit and receive sections have an extra amplifier stage and filter. For the layout, I made some sketches, calculated the important dimensions, and turned it over to Steve to have the CAD design done for the printed circuit. I know, this doesn't sound much like homebrewing, but I've already built a bunch of 10 GHz transverters by hand and have three spares to lend out — it's time to find another way to get more activity.

After several cycles of review and correction, we thought we had the data base ready for production of a trial lot of boards. While they were being made, I prepared some pipe caps so that I was ready to solder them on immediately, as shown in Figure 2. Then I added the brass stiffeners and started adding components; the completed prototype is shown in Figure 1.

Tuneup went quite well, since there are test points allowing each major section to be tested independently. I started with the LO, tuning each frequency multiplier section separately. When I connected them together, the output was a bit low, so I poked around and added a small tuning flag near the input to the second frequency multiplier stage, just after test point TP1. This brought the LO output at 10.224 MHz up to the level needed to properly drive a dual mixer, +7 to +10 dBm.

Next I connected the LO to the mixers and applied power to the transmit section. After tuning the pipe-cap filters, the output power was about +5 dBm, with very little LO leakage. The three stages of pipe caps provide adequate filtering.

Finally, I applied power to the receive section and peaked the receive filters on a strong signal from another transverter in the backyard. Then I used a noise figure meter for final tuning, which yielded a noise figure around 6 dB.

Once everything was tuned up, I checked the frequency stability. This transverter, like the 5760 MHz version and the no-tune units for lower frequencies, uses the KK7B oscillator board[10] for the 568 MHz LO source. At 10 GHz, the crystal frequency is multiplied roughly 100 times, so any instability is greatly magnified. For 5760 MHz, I found the stability to be marginal, with about a half-hour warmup required; at 10 GHz, it would be even worse. To improve the stability, we investigated small crystal heaters. I obtained some clip-on heaters from the RSGB component service[11], but, for some reason, the Japanese manufacturer is unable to find them in the USA. As an alternative, Steve tried some simple thermisters. These devices have a resistance that increases dramatically with temperature; when a voltage is applied, they draw

current, which produces heating, which increases the resistance, reducing the current. With the right combination of thermistor and voltage, a stable temperature is quickly reached. Steve found that soldering the thermistor to the crystal was a good way to control the crystal temperature and improve stability. With the thermistor in operation, the frequency stays within the receiver SSB passband after about one minute, and stability is good enough for SSB operation after less than 5 minutes. However, stray air currents can move the frequency a few kHz, so enclosing the heated crystal in a small block of foam insulation is probably a good idea for windy mountaintops.

The basic transverter performance is adequate for a modest rover station. It is comparable to the WBFM Gunnplexer system cited above, with a 30 dB potential advantage in signal bandwidth. Since the design provides sufficient filtering to provide a clean signal, it can also be the basis for a more advanced station, with the addition of power amplifiers, preamps, and large antennas.

Another advantage is low power consumption. The whole transverter may be powered from a 12 volt battery, and draws less total current than the surplus phase-locked oscillator bricks I used in previous transverters. A power amplifier would certainly increase power consumption, but only while transmitting, and most operators aren't calling CQ on 10 GHz.

The Final Version

Once the prototype was working, I went over it carefully and made a list of eleven changes. Steve added some improvements to aid producibility, plus provisions for some hotter MMICs that may become available, and sent it off to the CAD designer. The final layout is shown in Figure 4. Eventually, some corrected boards were produced, as well as the aluminum support plates and housings. These, plus the LO source board, an IF sequencer board, and voltage regulators for stable operation from 12 volts, make up a complete transverter unit. Figure 5 shows a unit during assembly in an extruded aluminum box made by Rose Enclosure Systems. All of the pieces are available from Down East Microwave.

Construction

The aluminum mounting plate is designed to aid in assembly as well as providing rigidity. The PC board is bolted to the mounting plate, and the pipe cap filters are aligned during soldering by the square holes in the mounting plate. Then the components are soldered on the surface of the board (some form of optical aid is useful for those of us who wear bifocals). A temperature-controlled soldering iron with a small tip is ideal for the chip components. However, the excellent grounding provided by the plated-thru holes requires more heat for ground connections, so a larger soldering may be needed for some connections. The blocking capacitors between sections should be placed initially so that the output of each section goes to a test point rather than to the next section.

This is how I prepare the pipe caps: in each pipe cap I drill and tap (use lots of oil) a hole in the center for a tuning screw: 4-40 thread for the ½" caps and 8-32 thread for the larger ones. Next, I

flatten the open end by sanding on a flat surface. Then I apply resin paste flux lightly to the open end and place it in position on the PC board — the flux holds it in place. Finally, I put some of thin wire solder around the base of each pipe cap. The caps are soldered one at a time, starting with the center one. I hold each cap down with gentle pressure and heat it for few seconds with a propane torch until the solder melts and flows into the joints, then let the solder harden before releasing pressure. Don't be shy with the torch — melt the solder quickly and remove the heat. Keep the flame on the top of the pipe cap to avoid damage to the PC board.

The input and output connections for the pipe-cap filters are plated-thru holes in the microstrip lines which are sized for a tight fit around the 0.7 mm diameter brass nails used as probes, so that the probes stay aligned vertically inside the pipecap. I measured the response of a single pipe-cap with different probe lengths; a shorter probe narrows the filter bandwidth but increases the loss. The recommended probe length is 5/32 " to 3/16" for the ½" pipecaps, where the length is measured to the head of the nail, so that the length inside the pipecap is shorter by thickness of the circuit board, 0.015". For the ¾" pipecaps, I found that I lengths of 5/16" for the first stage and ¼" for the second stage provided best performance.

Finally, the SMA connectors for 10 GHz transmit and receive are bolted through the end panel of the aluminum enclosure. Take care to line up the connector pins squarely on the microstrip lines, tighten the screws, and then solder the pins to the lines.

All other connections, both DC and RF, pass through clearance holes in the aluminum mounting plate. The RF connections should be made with small coax, properly grounded at each end.

Tuneup

The aluminum mounting plate is also designed to aid in tuneup, with extra tapped holes for mounting SMA connectors at the test points. The rigidity it provides also eliminates many of the intermittent problems encountered during tuning.

The KK7B LO source can provide a significant amount of output power, since it must drive a diode multiplier in some of the no-tune transverters. The MMIC multipliers need less drive, typically +5 dBm at 568 MHz. Steve has been developing a new LO source which uses a higher frequency crystal and provides a higher frequency output, at 1132 MHz for this transverter. At the higher frequency, even less drive is required; around 0 dBm (one milliwatt) is enough.

I recommend testing and adjusting one section at a time, starting with the LO. Monitor the output power at test point TP1 and power only the first two stages. The ¾" pipe-cap filters require one-inch long screws to reach 3408 MHz; screw them all the way in. Connect the LO source oscillator input and start tuning. Adjust the two screws out a half turn at a time until some output is detected, which should occur within a few turns. Then peak for maximum output, and check the power level and frequency, if possible. The tuning screws ended up with the flat part of the head about ¼ inch from the top of the pipe cap. The output power should be +4 to +9 dBm (or more) at 3408 MHz. Finally, check to see that the output level from the LO source

board is right for the frequency multiplier and not critical. Vary the output level from the LO source board (by adjusting its supply voltage; the 3408 MHz output should vary smoothly and not too rapidly as the voltage to the LO source board changes.

Now it is time to tune the rest of the LO. Move the blocking capacitor so that the 3408 MHz output is driving the next stage, and monitor the output level at test point TP2. The tuning screws on the ½" pipe caps should be ½" long with a 4-40 thread. Preset the two screws in the LO section so that the flat part of the head is 0.27 inches from the top of the pipe cap. Apply voltage to all the LO stages and start tuning in small increments until some output is detected. Then peak for maximum output, and check the power level and frequency, if possible. The output power should be +5 to +10 dBm (or more) at 10224 MHz. A LO power level in this range is fine for the dual mixer, but it will still work with somewhat less. Once again, vary the output level from the LO source board (by adjusting its supply voltage) to be sure that the right power levels are right for the frequency multipliers. If they are, the 10224 MHz output should vary smoothly and not too rapidly as the voltage to the LO source board changes.

The next section is the transmitter, which is tuned up in two steps. First, move the blocking capacitor so that the 10224 MHz output is feeding the dual mixer, and monitor the output power level at the transmit output connector. Preset the three tuning screws to match the final setting of the two in the LO section. Apply power to all LO and transmit stages, and start tuning in small increments until some output is detected. At this point, we are peaking the transmit filters on the LO leakage through the mixer, rather than filtering out the leakage. Peak the filters for maximum output — I typically see around one milliwatt.

Now it is time to add some 144 MHz input to the transmit mixer, from a signal generator or an IF rig. The input level should be about 0 dBm. We know that the filters are set at 10224 MHz, so the tuning screws must move out to raise the frequency. The required adjustment is less than one-quarter turn of each screw. Move them all out together (in sequence) by the same amount. The output will drop as we tune away from 10224 MHz and then increase as we reach 10368 MHz. Peak the output turning, favoring the high side to maximize LO rejection. Key the IF signal on and off to be sure that the output is due to mixing and not LO feedthrough. With proper tuning, the LO leakage should be more than 40 dB down. Finally, adjust the IF level to find the maximum linear output; if possible, vary the LO level as well to find the best operating point. After all, we don't want a lot of intermod on 10 GHz when it gets crowded!

To tune up the receiver, we need a reasonably strong signal at 10.368 GHz. It could be another 10 GHz rig, a signal generator or weak signal source, or a harmonic from a 1296 MHz rig, but it must be far enough away so that the signal is coming in through the antenna. Connect a receiver with an S-meter to the IF receive output, and some sort of small antenna to the receiver 10 GHz input connector. Preset the filter tuning screws to match the transmit filter setting as a starting point, then apply power to the LO and receive stages. Tune in the signal and peak the tuning screws for maximum S-meter reading. Do the usual checks to make sure the signal is coming in the antenna and isn't a birdie. If you have access to a noise figure meter, the tuning screws and voltages on the front end may be tweaked for best noise figure.

Performance Summary

After completing the adjustment procedure, the transmit power is about +10 dBm, or 10 milliwatts, and the receiver noise figure is around 6 dB. As a basic system with an attached horn antenna, these numbers are comparable to a Gunnplexer system in a similar sized package — except for the 30 dB bandwidth advantage for the narrowband system.

The output spectrum is reasonably clean, with the only outputs being leakage from the LO multiplier chain: -45 dBc at 10224 MHz, -30 dB at 6816 MHz, and more than 50 dB down at 3408 MHz. Since the transmit section has 3 filters, these are probably due to leakage inside the box, a result of the single-board construction.

Other than leakage, the LO chain is quite clean and delivers adequate power to the dual mixer.

The entire transverter board operates from a voltage of +8 volts. A 7808 three-terminal regulator IC, which guarantees stable operation with a battery voltage as low as 11 volts, easily supplies this power. Don't forget the recommended capacitors (0.1 μF) on the input and output of the IC, and adequate heat sinking; bolting it to the aluminum enclosure is probably enough. The complete LO current drain is about 330 mA, plus another 70 mA for the receive stages or 100 mA for the transmit stages. Thus, a complete transverter with coax relay and IF switch should not draw much more than ½ amp, less than most VHF transceivers.

10 GHz Systems

A basic transverter with a simple horn antenna is a good way to start out and is sufficient for any line-of-sight path. For higher performance, the single-board transverter can be the heart of a range of 10 GHz systems, from simple backpack rover system to a high-performance EME system. Obviously, the different requirements of these systems affect the choice of other components needed to get on the air. Weight and power consumption are critical in backpack systems, while performance is paramount for EME. Other systems, for home systems or vehicles, have intermediate requirements, but cost is a common constraint.

The pieces common to all systems include a source board for the LO, an IF interface, voltage regulators, some sort of enclosure, and an antenna. An IF transceiver is also needed to drive the transverter, typically at 144 MHz. The new MFJ-9402 SSB transceiver for 2 meters looks like a worthy successor to the venerable IC-202; I've been using one to tune up my latest transverter.

For the LO source, either the KK7B board with 568 MHz output or the new DEMI LO board with 1132 MHz output work very well. Another alternative would be a phase-locked source: the older "bricks" could drive the dual mixer directly from test point TP2, while some newer synthesized oscillators have output at 2556 MHz which could drive the second frequency multiplier from test point TP1. For stability, some sort of crystal heater or oven is recommended; for an EME station, a good oscillator that runs continuously is a possibility.

The IF interface handles the transmit-receive switchover and switches power to the appropriate part of the transverter. It can be very simple, but slightly more complex designs like my[12] "Fool-resistant IF sequencer" can help prevent untimely catastrophes. Don't try to get by with multiple switches which you throw in sequence — this is a recipe for disaster!

The transverter and LO boards are designed to operate from a regulated +8 volts, easily generated from a 12 volt battery with a simple three-terminal regulator like a 7808, with enough margin to keep going with when the battery gets low. Don't forget capacitors on both the input and output of the three-terminal regulator, to prevent oscillations and to keep out stray RF.

The enclosure has several crucial functions: it keeps internal frequencies inside, keeps stray RF out, keeps rain out of the electronics, and keeps out stray fingers. For portable work, a good enclosure is rugged enough to protect the contents when the wind blows everything over onto rocks. Metals are the best materials to meet all these requirements. However, the price of a new enclosure can be breathtaking. My secret is to look for useless old electronics at flea markets and surplus outlets that happen to be in a convenient size enclosure that I can re-use.

I haven't seen any solid-state switches that provide good 10 GHz performance at reasonable cost, so a TR relay is needed for most systems. The alternative is to use separate antennas. Small coax relays with SMA connectors are fairly common surplus items, and most of them will work at 10 GHz. Some of them have worn-out contacts, but a check for DC continuity while switching a few times will usually sort out the bad ones. Relays for 12 volt operation are rare, but it isn't difficult to rewind the relay coil[6].

The antenna is the real key to system performance, since an antenna of modest size can provide very high gain. The small horn antennas on Gunnplexer systems are ideal for beginners: they are rugged and easy to point and still provide 17 dB of gain. We later added a lens in front of the horn for additional gain. A larger horn can also provide higher gain, and horns almost always work as designed. Both horns and lenses are easy to design and build. My **HDL_ANT** computer program[13] does the calculations and even prints a template for horn construction.

Parabolic dish antennas can provide even higher gain. My favorite is the now-ubiquitous DSS satellite dish. These little 18" offset-fed dishes will provide more than 30 dB of gain with a simple horn feed[14] and cost only a few dollars[15]. Another advantage is that the transverter can be mounted just below the feedhorn without affecting performance, so that feedline loss can be minimized. Coax cable loss adds up quickly at 10 GHz, and there aren't any good ones. For more on antennas, refer to the *W1GHZ Microwave Antenna Book — Online* at *www.w1ghz.cx*

For better receive performance, a good preamp will help, if it is near the feed; otherwise feedline loss will limit performance. Many of us use a converted LNB[16] from a DSS system; the older ones (1.4 dB NF) are being replaced by lower noise ones, and brand new units are getting pretty reasonable. For even lower noise figure, you can homebrew a HEMT preamp. My favorite is a KH6CP design[17], which seems to work with almost any good transistor and provide a noise figure of 1 dB or less. The PC board is available from Down East Microwave.

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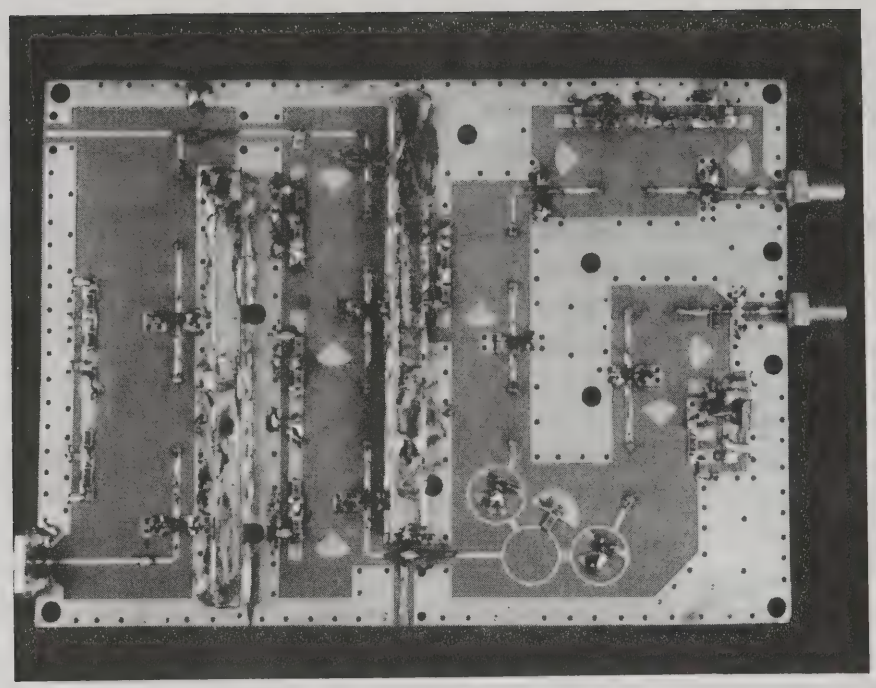


Figure 1. 10 GHz Single-board transverter prototype

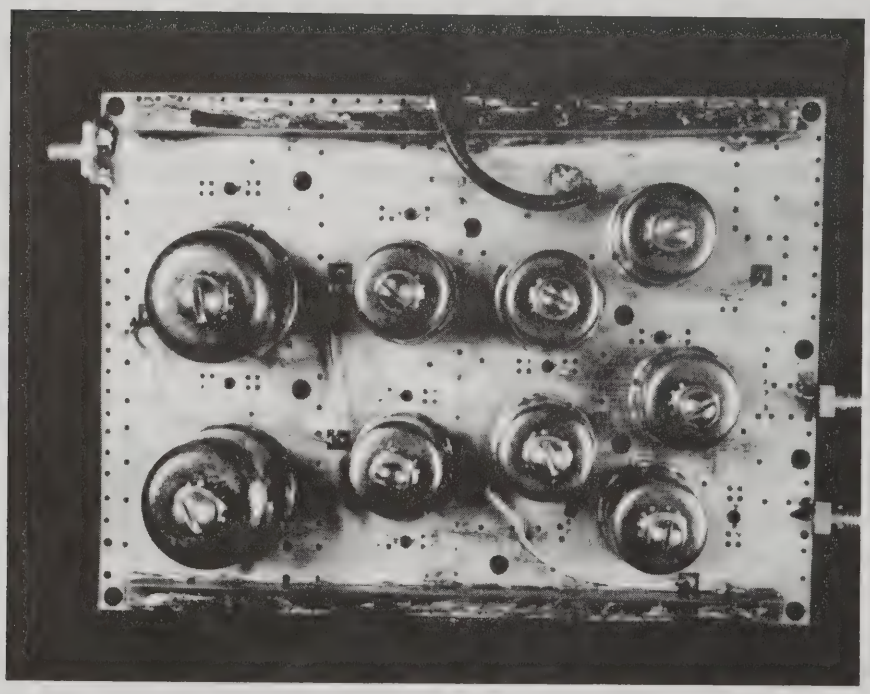
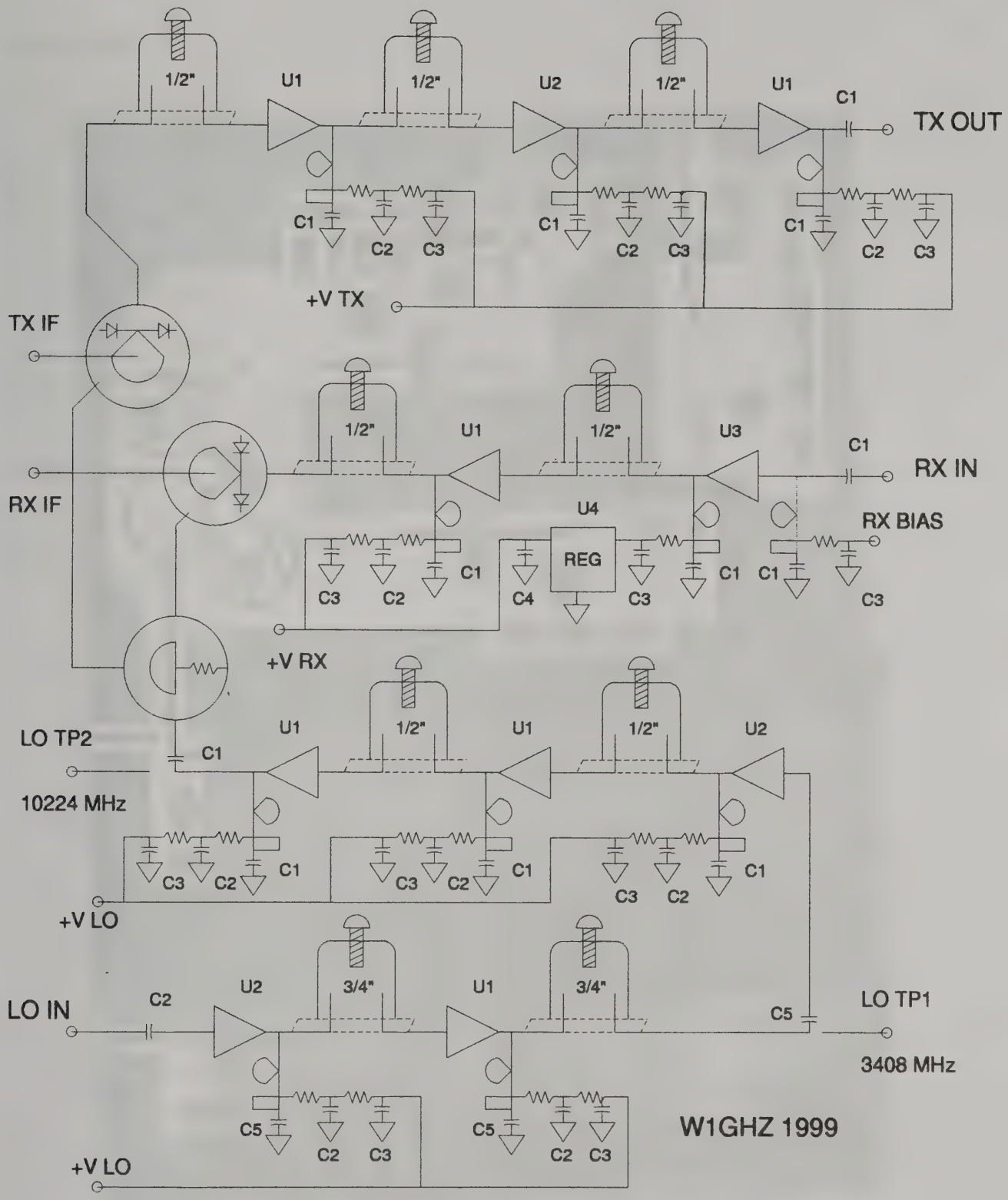


Figure 2. Pipe-cap side of transverter prototype



10 GHz SINGLE BOARD TRANSVERTER

FIGURE 3

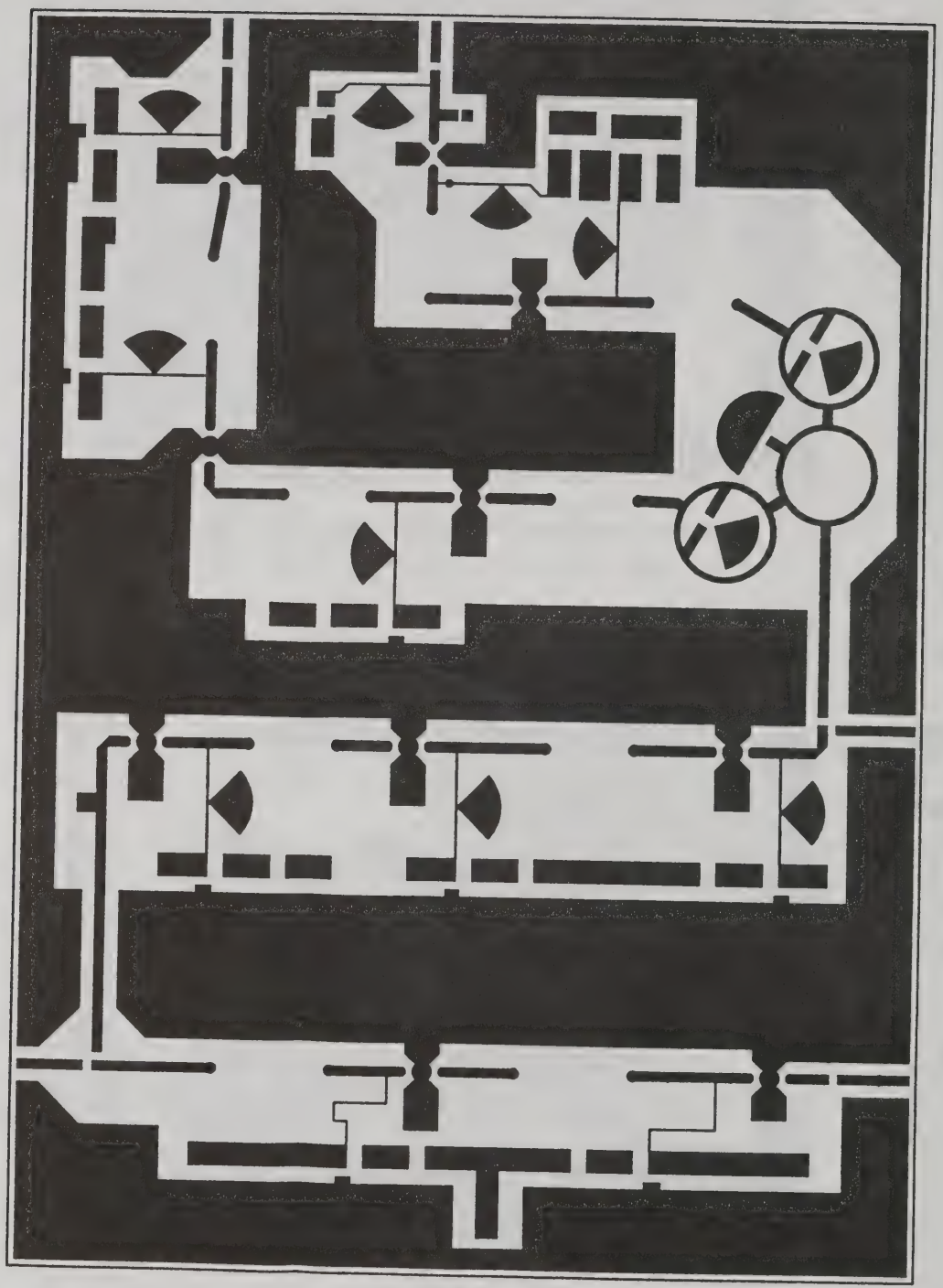


Figure 4. PCB layout for 10 GHz single-board transverter

Parts List

C1	1 pf ATC chip
C2	100 pf chip
C3	0.1 µf chip
C4	0.33 µf
C5	5 to 10 pf ATC chip
R(all)	51 ohm chip
U1	ERA-1 MMIC
U2	ERA-2 MMIC
U3	MGA-86576 MMIC
Mixer diode pair	HSMS-8202

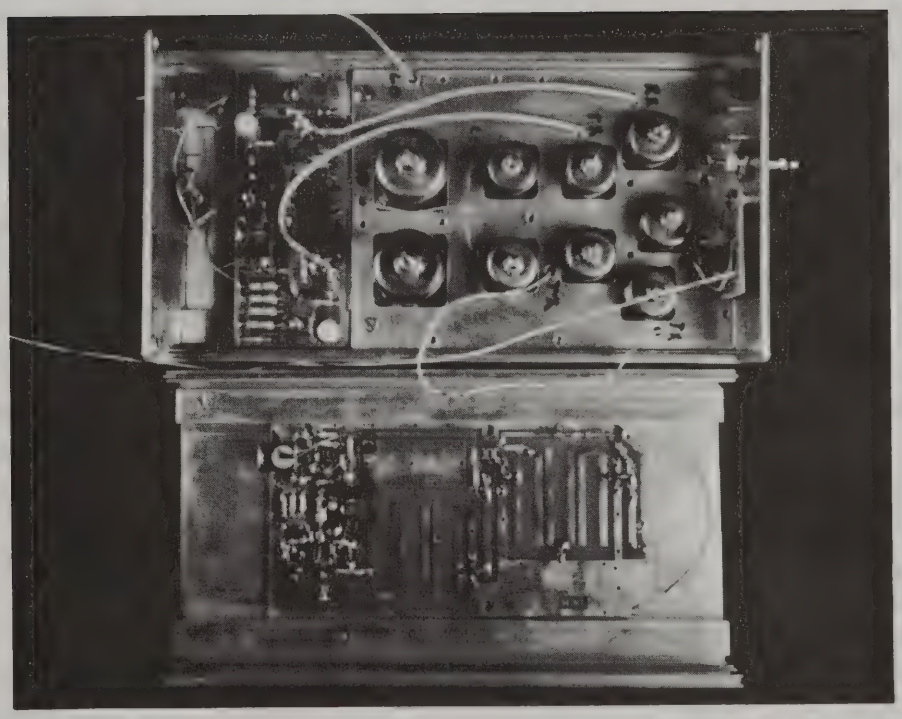


Figure 5. Basic system assembly with single-board transverter

Ground gain and radiation angle at VHF

Palle Preben-Hansen OZ1RH

Do you want an extra 5-6 dB gain? Do you want your radiation at an angle hitting the moon for eme? You may lose 10-20 dB at some angles and gain 5-6 dB at others. After this lecture you know why.

Contents:

1	FOREWORD	2
2	RADIATION ANGLE, GROUND REFLECTION AND GROUND GAIN	2
2.1	Flat Ground	3
2.2	Ground reflection point and 1. Fresnel zone	6
2.3	Sloping ground	7
2.4	Refraction and curved earth	8
3	MODELING RADIATION ANGLES BY COMPUTERS	8
4	STACKING, BLU SWITCHING AND BIP/BOP PHASING	9
5	POLARIZATION AND GROUND EFFECTS	10
6	CONCLUSIONS	10
7	ACKNOWLEDGMENTS	11
8	LITERATURE	11

Target group:

Eme'rs who want some theory on ground gain and radiation angle at 50 and 144 MHz and VHF amateurs who want to direct their radiation at some preferred radiation angle for a specific propagation mode (MS, Aurora, Es…).

Objectives:

After the lesson you should:
- know how to get 5-6 dB ground gain for eme
- know why radiation angle may differ from elevation of the boom

This lecture will be held in English but questions may be put in German and French (QRS s.v.p.).

Lecture by OZ1RH, operator at OZ9EDR/OZ5W contest team

1 Foreword

At the Weinheim UKW-Tagung 1995 I gave a lecture on Troposcatter at 50 MHz – 700km QSO's anytime. This lecture included something on ground gain and radiation angles. Now I want to share my findings on this with specific attention on its relevance for eme on 50 and 144 MHz.

To make my lectures more lively I do them without a fully written text and I base my speech only on my prepared overheads. Actually I have a PowerPoint presentation ready for you, so if the hardware will work you will experience some online simulations of ground gain. If you ask some interesting questions I will be happy to answer, and this will make the lecture even more interesting for you. My lecture may thus include other ideas than presented here, and you can't be sure it will include all of the following. So my best advise to you is to read the text and come to the lecture with some good questions.

My call is most likely unfamiliar to you. I was licensed in 1963 and qualified half a year before being 18 for my extra class license. I worked mostly HF and hold DXCC. I have done some 144 MHz contesting since the late sixties and for the last few years I have been in OZ9EDR/OZ5W contest team. I have no education in electronics, but hold bachelor degrees from the Copenhagen Business School of Commerce in public administration and organization, strategy and planning. I am employed in the computer business, so this text is based only on my leisure time study of the referenced literature and on my experience from the bands. I know my words are not the whole truth, but I hope they come closer to "nothing but the truth".

I admit my eme experience is very limited. Some years ago I have heard a few stations on 144 MHz including KB8RQ so strong I thought he was a local. He had very deep QSB and today I know ground reflections may give deep QSB. On 50 MHz the eme signal of OZ5W has been seen with FFTDSP by W7GJ and I heard fractions of him just at the time where I had calculated we both had ground gain.

In the sixties I was active on HF and I learned a little on radiation angles at HF. In the beginning of the nineties I started being active on VHF from OZ9EDR/OZ5W and I wondered if ground reflection and radiation angles applies to VHF. I found it does indeed, and now I want to share this knowledge with you.

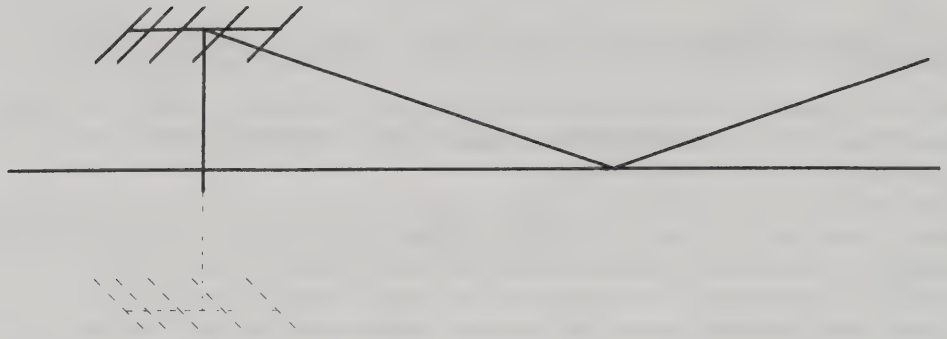
Much of the literature I have read dates back to 1954-60, where propagation around 50 MHz was a hot item among scientists and radio engineers. They knew about radiation angles and ground gain.

Limitations of the subject:
Ground reflections applies to all frequencies, but here I concentrate on the effects at 50 and 144 MHz. On the higher bands your antenna will be many wavelength up and ground reflections does not play a significant role. Above 432 MHz sky noise temperature is lower than ground noise temperature so illuminating the ground with your beam pattern to get ground gain will increase noise in your RX.

The first chapters are based on horizontal polarization unless specifically noticed. Vertical and circular polarization is mentioned in the later chapter on polarization and ground effects.

2 Radiation angle, ground reflection and ground gain

The radiation angles are the angles where the transmitted signal and the signal from the ground image of the antenna are in phase. You can imagine your antenna is in front of a large reflector (dish) where you could place the antenna at the focus point to get most gain. This gain is typically 5-6 dB but dependent on the shape of the ground in front of the antenna and the antenna height.

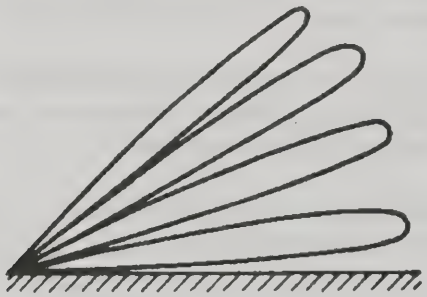


2.1 Flat Ground

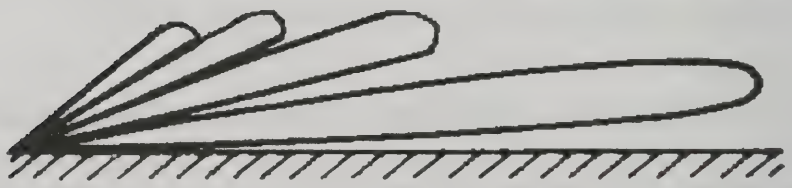
The following radiation angles can be calculated for a QTH on a flat ground:

Beam height over flat ground in meters	432 MHz	144 MHz	50 MHz
10 m	1 °	3 °	9 °
20 m	0,5 °	1,5°	4 °

A horizontal polarized antenna being many wavelengths up will have a radiation pattern with many loops in the vertical plane:

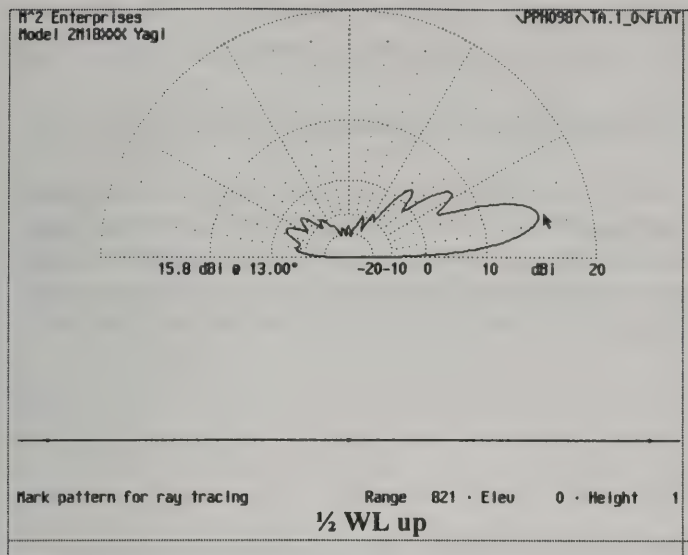


Horizontal dipole many λ up

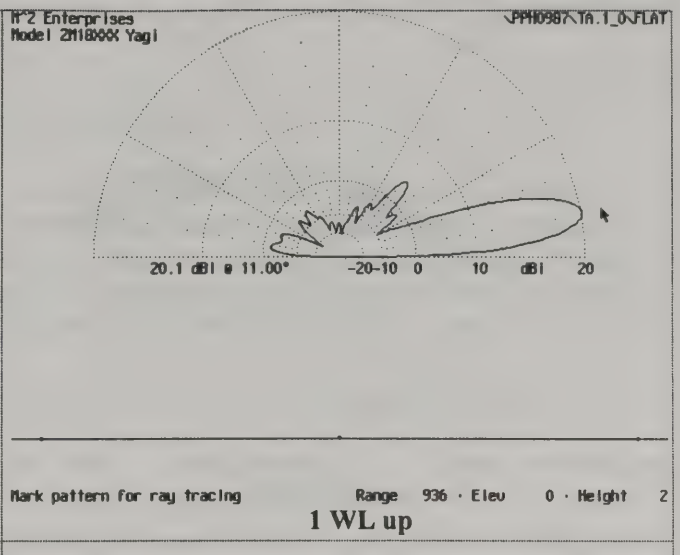


Horizontal beam many λ up

In order to get the vertical pattern of a beam over ground, one should multiply the pattern of a dipole over ground with the free space pattern of the beam. At angles where the dipole gives zero radiation the beam will also have zero radiation (in practice "only" -10 to -20 dB with average ground). Good ground conductivity produces deeper minima.


M^2 Enterprises
Model 2M18XXX Yagi
\PPH0987\TA.1_0\FLAT
15.8 dBi @ 13.00°
-20 -10 0 10 dBi 20
Mark pattern for ray tracing
Range 821 · Elev 0 · Height 1

½ WL up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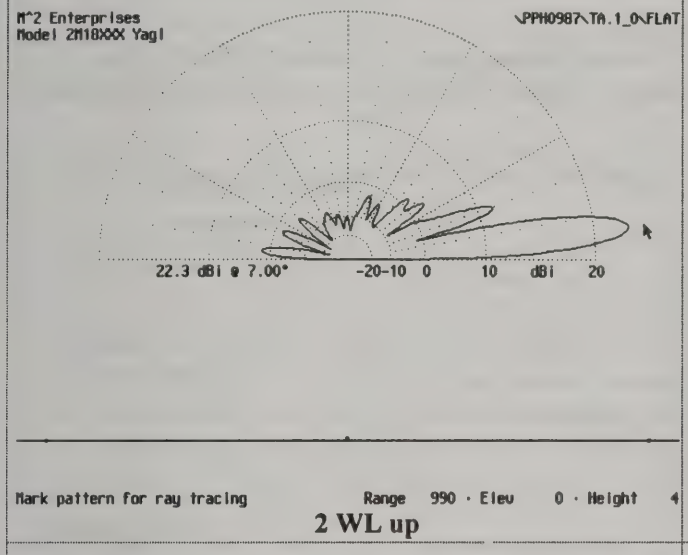
-20 -10 0 10 dBi 20
Mark pattern for ray tracing
Range 936 · Elev 0 · Height 2

1 WL up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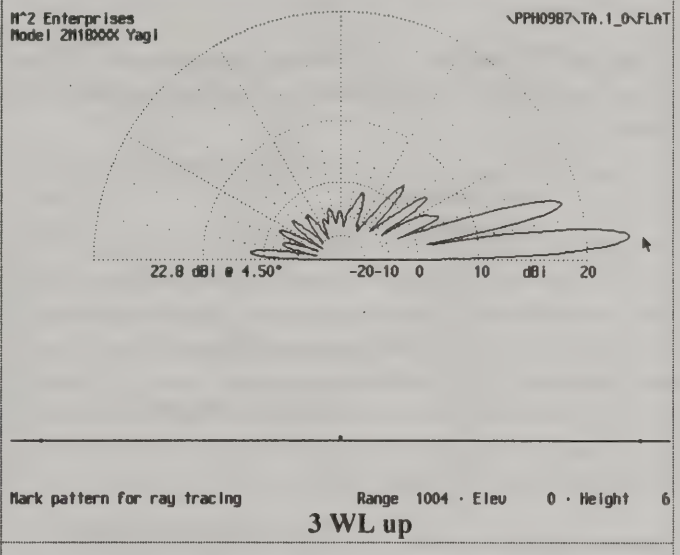
Model 2M18XXX Yagi
\PPH0987\TA.1_0\FLAT
22.3 dBi @ 7.00°
-20 -10 0 10 dBi 20
Mark pattern for ray tracing
Range 990 · Elev 0 · Height 4

2 WL up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Model 2M18XXX Yagi
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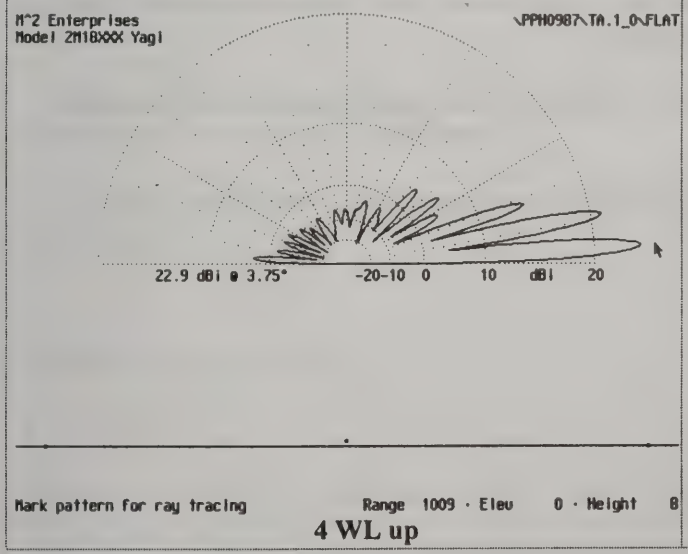
Mark pattern for ray tracing
Range 1004 · Elev 0 · Height 6

3 WL up


M^2 Enterprises
Model 2M18XXX Yagi
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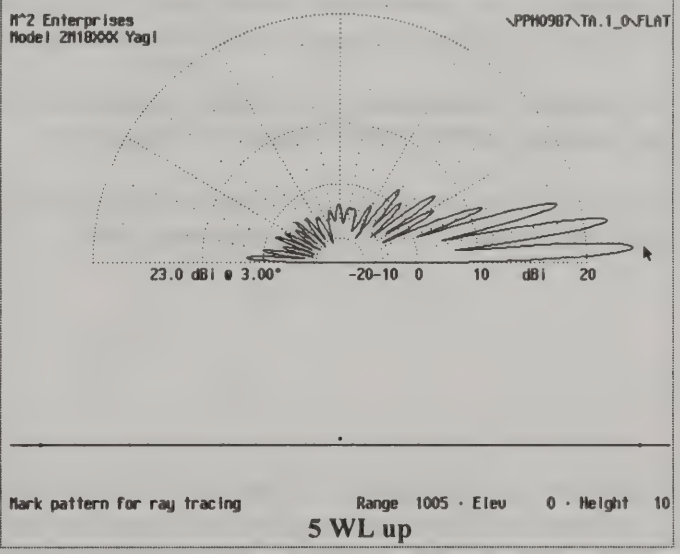
22.9 dBi @ 3.75°
-20 -10 0 10 dBi 20
Mark pattern for ray tracing
Range 1009 · Elev 0 · Height 8

4 WL up


M^2 Enterprises
Model 2M18XXX Yagi
\PPH0987\TA.1_0\FLAT
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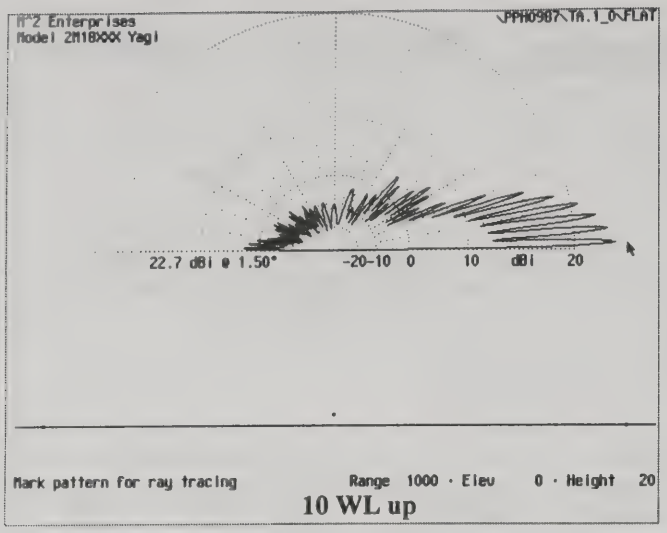
-20 -10 0 10 dBi 20
Mark pattern for ray tracing
Range 1005 · Elev 0 · Height 10

5 WL up


M^2 Enterprises
Model 2M18XXX Yagi
\PPH0987\TA.1_0\FLAT
22.7 dBi @ 1.50°
-20-10 0 10 dBi 20
Mark pattern for ray tracing
Range 1000 · Elev 0 · Height 20
10 WL up

A 2M18XXX has app. 15,3 dBd free space gain or 17,5 dBi. If this approximate value is subtracted from the gain values calculated by Terrain Analyzer we get an *estimate* of the ground gain. The following data can be taken from the curves:

Antenna height over flat ground	App. ground gain in dB	Maximum radiation at degrees
½ λ	-1,7	13
1 λ	2,6	11
2 λ	4,8	7
3 λ	5,3	4,5
4 λ	5,4	3,75
5 λ	5,5	3
10 λ	5,2	1,5

I have shown the figures as read from the plots, but remember that the calculations are not accurate to neither a fraction of a dB nor a fraction of a degree. Take the values only as a tendency.

It is seen that the antenna needs to clear the ground by at least 2 λ to get about 5 dB ground gain over flat ground and the ground gain will be at in the range of 7-1 degree.

The plots also show that the higher up the antenna gets the power will be split into more and thinner loops, and the higher loops have little less gain than the lowest loop.

2.2 Ground reflection point and 1. Fresnel zone

Let us examine the basic geometry and formulas involved if the ground is flat.

Radio waves between two points mostly propagate within a so-called 1. Fresnel zone, which may be imagined as a cigar formed tube. The loop in the vertical radiation pattern of a horizontal beam over reflecting ground is formed by phase interference between the direct and the wave reflected on the ground. The ground doing the reflection is mostly the ground within the 1. Fresnel zone between the distant station and the ground image of your antenna. The geometry is shown on the following figure taken from "The scatter propagation Issue": Proc. of the IRE, October 1955, p. 1228:

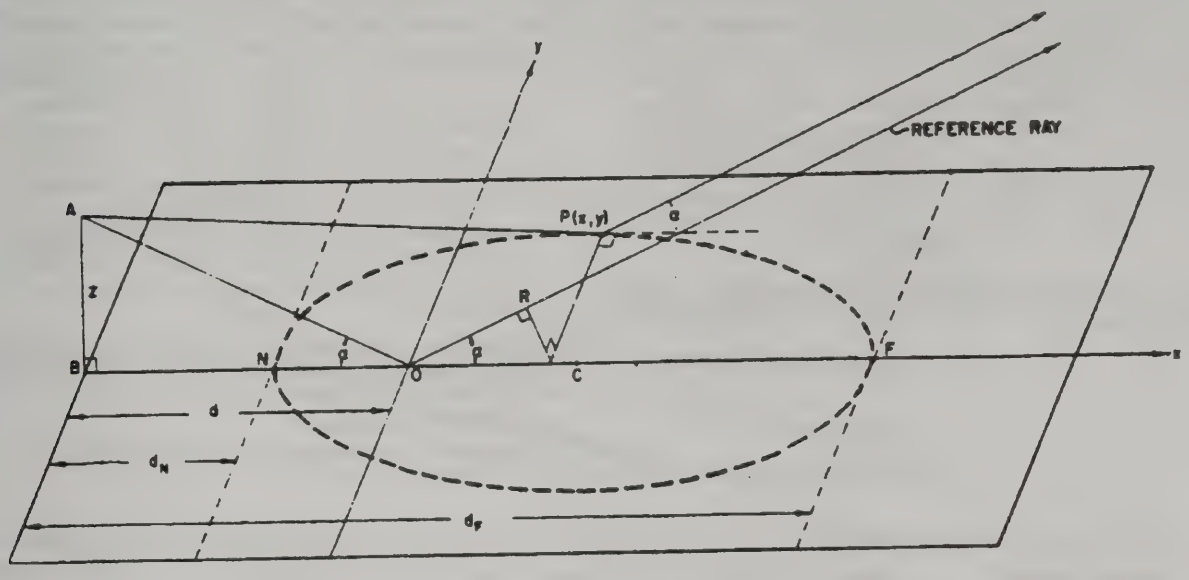


Fig. 64—Geometry of first Fresnel zone.

Antenna height :

$$z = \frac{\lambda}{4 \sin \alpha}$$

Distance to reflection point :

$$d = \frac{z}{\tan \alpha}$$

Distance to near edge of first Fresnel zone:

$$d_N = d \left(3 - \frac{2\sqrt{2}}{\cos \alpha} \right)$$

Distance to far edge of first Fresnel zone:

$$d_F = d \left(3 + \frac{2\sqrt{2}}{\cos \alpha} \right)$$

Maximum width of the zone:

$$w = 4\sqrt{2}\, z$$

The ground within this 1. Fresnel zone should be able to reflect VHF. If it is covered with houses (suburban area) or has many small irregularities (rocks) you get little reflection and ground gain. If you are in a suburban area you may have noticed your neighbors within the 1. Fresnel zone often gives you a call (if their phone works!) complaining about TVI and you probably have noticed you can hear many computers and other noise sources from this area. So even if you could have ground gain for transmitting the noise sources may mask reception from the low moon angles, thus you have little use of ground gain from such a QTH.

I have found some curves, which may help you to estimate radiation angles and ground reflections at 50 MHz for flat ground:

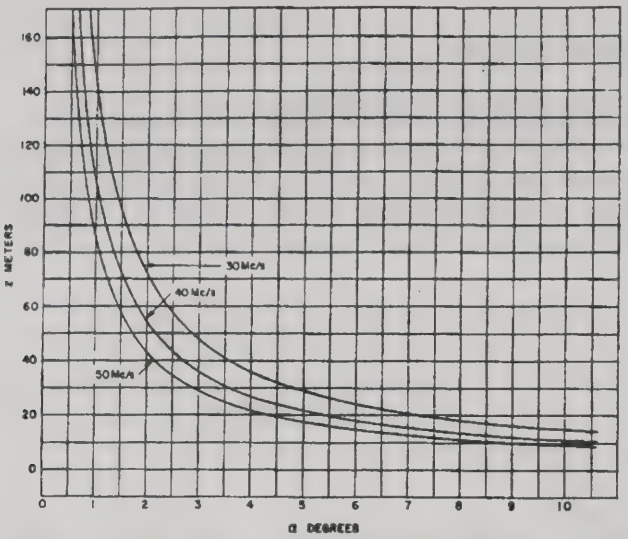


Fig. 65—Antenna heights for aligning first ground-reflection lobe maximum at indicated elevation angle, for horizontal polarization and a plane earth.

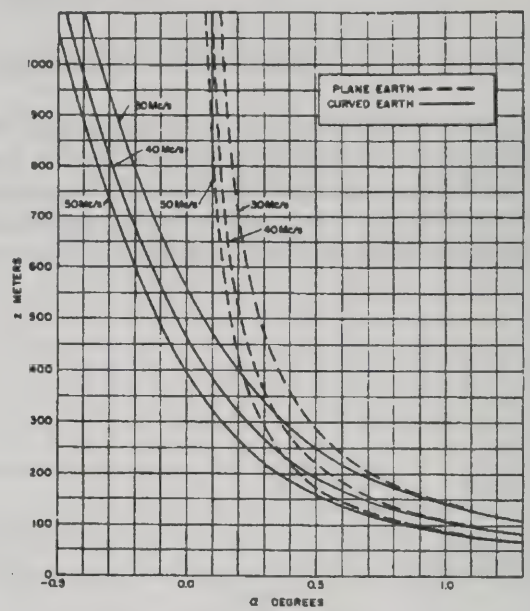


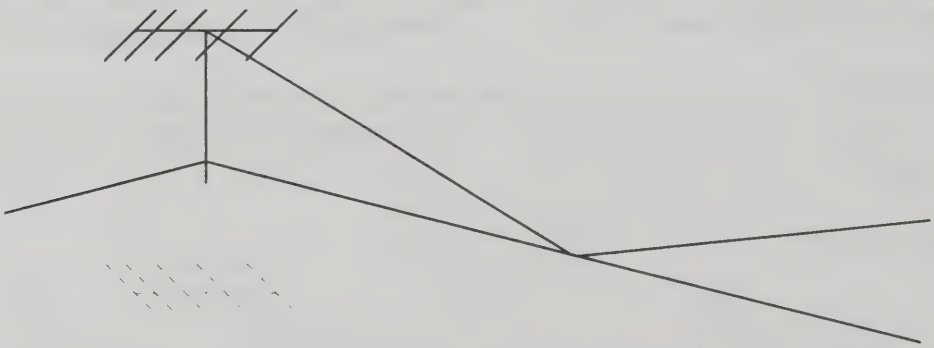
Fig. 66—Antenna heights for aligning first ground-reflection lobe maximum at indicated low elevation angle for horizontal polarization, for plane and curved earth.

IRE Transactions on Communication Systems, March 1960, p. 14-19

2.3 Sloping ground

Most amateurs do not live with perfect flat reflecting ground around them, thus it is important to know what happens to the radiation angle when the ground is not flat. I hope your ground is sloping down, if not you are in a hole which makes low angle radiation with ground gain difficult. No ground gain will let you radiate though mountains for eme...

If the reflecting ground is sloping down low radiation angles are possible without a high tower and you may even get a vertical radiation pattern without loops. The downward slope of the hill subtracts something from the radiation angle compared with flat ground.



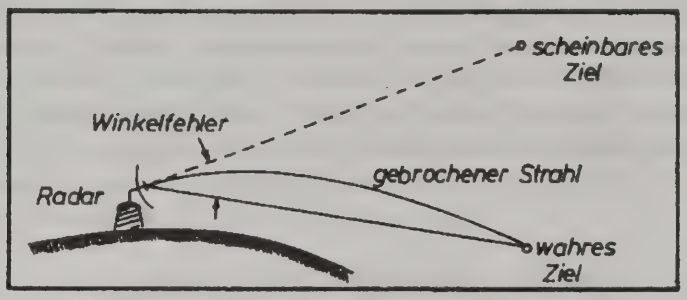
If you have a hill with a long enough slope of 20° your antenna needs only to be ½ λ up and it will illuminate all radiation angles from less than 1° to 10°. If you put your antenna up higher at this QTH, you may get loops and consequently also some minima in the vertical radiation pattern. Hilltop QTH's are complicated regarding radiation angles and computer calculations are needed to get just an estimate.

In order to get ground gain your antenna must illuminate the ground. If you have sloping ground this could mean your antenna should aim down along the slope, that is have negative elevation in order to get maximum ground gain.

30 years ago I had a student job recording weather pictures from low orbiting ESSA/Nimbus satellites. We used 4x10 elm at 136 MHz about two wavelengths up. The automatic tracking system, as I recall, measured the phase difference of the 4 beams to adjust for max signal. Sometimes it locked to the ground-reflected wave and tried to force the antenna booms to negative elevation angles. At that time I was told this was an error, but today I think the ground reflected signal was stronger than the direct one at low angles.

2.4 Refraction and curved earth

For very low radiation angles refraction in the atmosphere should also be taken into account. Refraction is the effect of the diminishing refractivity of the atmosphere with increasing height (air gets thinner and lees humidity higher up) causing the radio wave to be bent (refracted) towards the earth. This refraction is also known as 4/3 R, meaning that to radio waves the earth looks flatter, as if its radius were 4/3 of its actual radius. Diffraction around the round earth has a minor but similar effect.



This drawing illustrates how refraction so to say 'lift the moon' a low moon elevation. To hit the moon at very low elevation angles we must radiate at little higher angle than the direct path to the moon.

This is why you can have echoes after moonset. The programs used for calculating moon position do not mention this, so I suspect they do not take this refraction into account. The effect is probably less than 1 degree and as our beams are not pencil sharp and our rotators not accurate to fractions of a degree we do not have to care unless we are on 10 GHz with a big dish. And in that case one would track the moon via moon noise, and then no problem with refraction.

A similar effect happens in the ionosphere but is hard to predict as the ionosphere changes ionization along the path of your eme signal in an unknown manner. The ionosphere may focus or defocus your signal and this effect is more pronounced at the lower frequencies.

Also for very low angles of radiation it must be considered that the earth is not flat but curved. For angles of radiation less than about 1° d will decrease and d_F will decrease even more, but d_N will be almost unchanged. This has not much practical importance.

3 Modeling radiation angles by computers

In order to calculate the radiation angle from a QTH it is important to know where the ground reflection point will be and how much of the ground will contribute with reflections. This can be calculated by software. I know of the following packages doing this:

1. YTAD from ARRL FTP or BBS. Look for QEX-files
2. YT bundled with ARRL Antenna Handbook 1997
3. Terrain Analysis 1.0 by K6STI, 80 USD

YTAD is freeware and described in QEX July 1995. This article tells much on radiation angles and calculation. The method and the shortcomings of the software are mentioned. This is important as most computer freaks think everything printed by computer is the truth. I hope you know better, after all this text is printed by computer…

YT is a newer and improved version of YTAD. Both programs are designed for HF use and the resolution is only 1 degree in the final plot although YT calculates for every ¼ degree. Both YTAD and YT includes important information on the statistically most needed radiation angles for HF propagation, but this has no relevance at VHF

Terrain Analysis (TA) has more options and a better display of the results than YT or YTAD. It is TA I use most but I sometimes verify my calculations by YTAD or YT. I have found all the programs give similar results. That is no wonder as the principal calculation method and diffraction theory behind the programs are the same. TA can model vertical polarization, YTAD and YT only does horizontal polarization. I might as well warn you right away, read the later chapter on polarization and you might conclude that vertical polarization and ground gain does not go too well together. If you insist on trying vertical polarization TA is the program to try. In TA you can set many parameters, you better read the manual and know what you are doing. For maximum accuracy I recommend you set 1/4 deg resolution, Slope consolidation 0.1 deg, Diffraction threshold -20 dB and over average ground.

The accuracy of these programs is likely to be better than +-3 dB, but do not stake all your money on more than 3 dB accuracy for the lowest loops where ground gain happens. The deep minima and the high angle loops around 90 degrees are not believed to be very accurate but this is of little interest to us. At least I do not care whether a minimum is –10 or –20 dB at a certain angle as there will be no QSO at that angle anyway. These programs are designed for HF and higher radiation angles and use less resolution than VHF amateurs could desire. Thus it the results should be evaluated and obvious unreasonable results discarded. This is noticed in the readme.doc's.

4 Stacking, BLU switching and BIP/BOP phasing

The angle of radiation for horizontal polarization is only dependent of the antenna height over reflecting ground. Using stacked beams will concentrate the energy at the lowest radiation angle determined by the average antenna height, so stacking does not "pull down" the radiation angle significantly.

The vertical pattern in free space of a two-beam vertical stack is 1/2 of the single one, measured as the 3 dB opening angle. This angle is much different from the radiation angle. The radiation angle over reflecting ground is not lowered if both antennas are several wavelengths up and the center of the stack is at same height at the single antenna. But the stack will radiate more in the lowest loop, and give the theoretical 2.5 to 2.8 dB gain also at the lower part of the lowest loop.

If your mast height is fixed stacking will lower the average height of your stack by half the stacking distance. The radiation angle from the stack will then be higher than the radiation angle of the top beam alone. This is most noticeable at mast heights of only a few wavelengths. Stacking does not help much for radiation at very low angles = much lower than the lowest loop. It seems difficult (impossible?) to force energy into the lowest radiation angles if the mast is not high enough. The effect is very noticeable at 50 MHz where mast/towers seldom are very high measured in wavelengths.

If you want to control your radiation angle and have ground gain you must be able to change the height over ground of your antenna. It was done around 1942-43 where the Germans had a radar system for finding the height of enemy planes. The system ran around 222 MHz and employed antennas that were moved up and down between two masts to control the radiation angle. This is not very practical, how many eme antennas are on a remote controlled telescopic tower? But it can be done, there is one in PA0. A small antenna take advantage of 5-6 dB ground gain and sounds as a big antenna.

One trick could be to be able to switch between using only the upper or lower beam of a stack. HF-DX freaks know about a BLU-switch (Both, Upper, Lower). This could be supplemented by feeding one of the antennas 180° out of phase by switching in a ½ λ phasing cable in one of the feedlines. This is called BIP/BOP phasing which stands for Both In Phase/Both Out of Phase. Most people who had tried out of phase stacking on HF reports that it is not productive, either beam alone or the stack is always better. I would not try BOP for eme.

5 Polarization and ground effects

For DX-ers on HF it is well known that the radiation angle of a *horizontal* polarized beam is a function of its height over the ground and ground conductivity has little influence on low angle of radiation. Things are different for vertical polarization. A vertical antenna needs perfect ground to give low angle of radiation. In fact is does not radiate at all below an angle called the Brewster angle. This angle is dependent of the conductivity of the reflecting ground. Check an antenna book on verticals for 80 m, the 80 m DX'ers know all about this. Does low angle of radiation interest us for VHF? Yes ground gain is happening in the range of 0-10 degrees.

	Horizontal polarization	Vertical polarization
Ground gain for one reflection	5-6 dB	Perhaps 3 dB
Ground conductivity	Little influence at low angles	No radiation below Brewster angle 5-20 degrees
Lossy ground	Little less ground gain and not so deep nulls in pattern	High Brewster angle 20 degrees?
Good ground conductivity (salt water)	Deep nulls in pattern, but peak almost uninfluenced	Low Brewster angle < 5 degrees?

It seems a good idea to use horizontal polarization if one wants low angle of radiation. Vertical polarization has less ground gain. A circular polarized signal contains two components: a horizontal polarized and a vertical polarized one. Ground reflection influence the two components differently as describes above and after ground reflection the signal is no longer circular but somewhat elliptical polarized at low radiation angles.

6 Conclusions

Ground gain is available at VHF for low angle radiation and horizontal polarized antennas at heights of app. 1-5 wavelengths. Ground gain can be 5-6 dB and is easily estimated over flat ground using simple formula or monograms. For non-flat ground QTH's (=hilltop I hope), things gets quite complicated but ground gain can be calculated with reasonable accuracy by software designed for amateur radio use at HF.

In order to get ground gain your beam must illuminate the ground. For low angle eme up to 5-10 degrees your elevation rotator should show zero degrees depending on your antenna height and terrain. On a hilltop QTH a negative elevation that is beaming along the downward slope might result in best ground gain.

Several angles apply to antennas over ground:

1. ½ power beamwidth in the vertical plane is known from the data sheet of the antenna. Typically +-13 degrees for one long boom yagi M^2 18-XXX, half for a vertical two plane stack

2. Elevation angle of the boom. This is the angle displayed by your elevation rotator. Could well be zero or even negative

3. Angle of max radiation which is the angle of the lowest loop in the radiation pattern formed by interaction of the direct ray and the rays reflected by the ground. The radiation angle is always higher than the elevation angle of the boom as long as there are ground effects

Ground effects favor horizontal polarization for low angle radiation.

7 Acknowledgments

Many people helped providing the basis for this text. It was fun to write, but no easy crack. *Food provided by Mac Donald's, beverages by the Coca-Cola Company and the midnight oil burned using Brazilian coffee .... .. Greets to*

Brian Beezley, K6STI for developing Terrain Analyzer
Dean Straw, N6BV for developing YTAD and YT
Microsoft for the possibility of getting nice WareZ: Win95, Word 97 and PowerPoint97
Intel for a VHF Pentium (150 MHz)
Compaq for fitting above in a LTE 5000 notebook
OZ5W/OZ9EDR contest team for trying out many QTH's and putting up some pretty big /P antennas for evaluation during contests. Behind the scene is Torben, OZ1BGZ who creates many fancy mechanical details with an accuracy which usually only exists in the logical world. Software may help, but some antenna hardware is needed to create radiation!

8 Literature

E. Fich and R. Ruddlesden, "The choice of aerial height for ionospheric scatter links", Proc. IEE, vol. 105, pt. B, suppl. 8, January 1958, p. 12-18 ← the whole volume is 200 pages of interesting stuff on tropo- and ionoscatter propagation
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Brian Beezley, K6STI, ta.doc Documentation for TA 1.0 TERRAIN ANALYZER 1995 by

A little advertising is coming your way also. My practical experience with radiation angles comes from contesting where antennas and propagation can be judged and compared with the other combatants. OZ5W/OZ9EDR contest team tries to make DX QSO's regardless of band conditions, but we need someone at the other end to make a QSO. Please try looking for OZ9EDR or OZ5W in major contests and 19-23H local time:

1.st Tuesday of the month:	144.280 SSB/CW +.305 2x8874 2x18elm M2+2/4x9elm
2.nd Tuesday of the month:	432.180 SSB/CW 3CX800A/4CX400A 4x20elm+2x21elm
3.rd Tuesday of the month:	1296.180 SSB/CW OZ1BGZ 70 W at 4x37 elm JO65AP
4.th Tuesday of the month:	50.160 SSB/CW 2x8874 1kW 2x6elm /P JO55KR

We mostly have one beam to the south (DL and PA0) shortly after 19H local and to the northeast (SM and OH) around 21H local. We do troposcatter QSO up to 700 km and on 50.160 meteorscatter from 1.100-1.600 km. Skeds may be arranged. Please exchange full 6-digit locator. We are in JO55UL or /P likely at JO64GX or JO55KR.

I can be contacted at:

E-mail: oz1rh@dialip.csc.dk
Phone: +45 46 78 77 67
GSM: +45 40 36 77 67
Email to SMS: 40367767@sms.tdm.dk

Snailmail:
Palle Preben-Hansen
Soderupvej 104
Ågerup Mølle
DK-4000 Denmark

Sri no packet, life is too short for QRP and 1200 bps!

© OZ1RH

Everyday VHF, UHF, and SHF propagation
700 km DX anytime using troposcatter

Palle Preben-Hansen, OZ1RH

If you are you an experienced DX'er you know that most stations work stations 5-800 km away in the VHF/UHF contests regardless of band conditions. How come you can make a 700 km QSO on a dead band?

Are you a FM-freak and gossip through your local repeater? Then you may want to have a range of 3-400 km on 2 meter or 70 cm with simple equipment.

With 10 W SSB on 144 MHz and a 10 dB horizontal antenna the range on troposcatter is over 300 km, much better than a repeater. 100 W SSB and a 15 dB antenna in the clear you make 500+ km anytime. Troposcatter works from 50 MHz to over 10 GHz.

Troposcatter is responsible for most daily QSO's and contest QSO's, but perhaps also the least known propagation. In this lecture troposcatter is examined inside and out, in order for you to learn how to make best use of a propagation, which is always there.

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Troposcatter - daily DX!....4
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Airplane reflection or troposcatter....15
Greater range on 70 cm than on 2 m....16
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Target group:
Those who think VHF and UHF can only be used to chat via the local repeater, and the experienced DX-freaks, who would like to know why they can work so many stations so far away and what it takes to improve the range.

Objectives:
After the lesson the participants should:
- know about troposcatter propagation
- have a general idea on what equipment is needed
- know why the range is limited to app. 800 km

This lecture was given at the Weinheim UKW-Tagung 1994, but I have now updated and enhanced it with new knowledge and experience from the past 5 years. It will be held in English, but questions may also be asked in German and French (QRS s.v.p.).

Lecture by OZ1RH, operator at OZ5W/OZ9EDR contest team.

© OZ1RH

Preface

My call is not heard often on the bands. I was licensed in 1963 and qualified half a year before being 18 for my extra class license. I worked mostly HF and hold DXCC. I have done some 144 MHz contesting since the late sixties and in the beginning of the nineties I started being active on VHF from OZ9EDR/OZ5W. I wondered which propagation made us work 700 km in every contest. I read some books, and found troposcatter does the trick. Now I want to share this knowledge with you.

I have no education in electronics, but hold bachelor degrees from the Copenhagen Business School of Commerce in public administration and organization, strategy and planning. I am employed in the computer business, so this text is based only on my leisure time study of the referenced literature and on my experience from the bands. I know my words are not the whole truth, but I hope they come closer to "nothing but the truth".

Much of the literature I have read on scatter dates back to 1954-60, where it was a hot item among scientists and radio engineers. I trust we may still use this old information, as the characteristics of the propagation itself have not changed in the past 40 years.

Troposcatter was used by commercial services and the military 1950-93, so information on troposcatter was to some extend restricted in those days due to security reasons. Some of the sources I have read mention "Printed with permission of the Admiralty" or "Some essential parts are deleted due to US government policies". Thus troposcatter so far has been quite unknown to many amateurs.

Today troposcatter is little used commercial, as satellite communication is available. Troposcatter is however still used over the North Sea for communication with the oil platforms. Paying no attention to the lack of commercial use, radio amateurs working on an otherwise dead VHF/UHF/SHF band do take advantage of troposcatter communication most often during contests.

To make my lectures more lively I do them without a fully written text and I base my speech only on my prepared PowerPoint slides with overheads as backup in case of PC panic. If you ask some interesting questions I will be happy to answer, and this will make the lecture even more interesting for you. My lecture may thus include other ideas than presented here, and you can't be sure it will include all of the following. So my best advise to you is to read the text and come to the lecture with some good questions.

Tropospheric propagation terminology

Many amateurs talk about 'tropo propagation'. The word 'Tropo' is not in any of the books or research articles on propagation I have read. It seems amateurs uses the word 'Tropo' for various propagation modes taking place in the troposphere because they do not know better. The word 'Tropo' should never be used alone. The relevant propagation modes in the troposphere are:

Line of sight (0-30 km, depending on height) is always available. The antennas see each other and have more or less clearance of 1. Fresnel zone. Generally S9 signals with QRP.

Diffraction (30-100 km?). Waves follow the curved earth a little, thus extending line of sight somewhat. Knife edge diffraction in mountain areas is a better known but special case of diffraction.

Refraction. (30-100 km?). Waves bent towards the earth due to the fact that the atmosphere gets thinner at higher altitude. Actually humidity plays a greater role than atmospheric temperature and pressure. Diffraction and refraction combined extends line of sight range, but signals will have QSB.

Inversion (200+ km ?). Temperature/humidity can sometimes suddenly increase at higher heights, 100-1.000 m up and our radio waves are reflected back to earth.

Ducting (1.000+ km, e.g. Hawaii to California at 4000 km). Radio waves are sometimes trapped like in a wave guide between an inversion layer and the ground or between two inversion layers. Little attenuation, thus good signal strengths. Often signals are only heard at each end of the wave guide, and conditions are only good between relatively small geographical areas.

Troposcatter (100-700+ km). Scattering in the troposphere in the common volume of the radiation from the beams. This is what will be discussed in details in the following.

All the above mentioned propagation modes are of tropospheric origin, where the cause of propagation is some kind of change in the refractive index of the atmosphere - that is change in temperature, density and humidity.

Troposcatter is to some extend influenced by the climate. The following is only dealing with a temperate climate like in northern or central Europe. If you are in an equatorial, sub-tropical, desert, Mediterranean or polar climate zone please read the texts from CCIR Study Groups, ITU, referenced at the end.

4/3 earth radius = radio optical view to DX?

As long as you have line of sight to your QSO partner you have good signal strength even from a FM walkie. Depending on how good your QTH and how high your tower is you could have line of sight up to 30-50 km.

Diffraction and refraction extends your range beyond line of sight, but signals will have QSB in this diffraction zone. This means that the radio horizon is further away than the optical horizon, and this diffraction and refraction effect is often modeled by assuming the earth is flatter than it really is, that is it is a sphere with 4/3 radius of the real earth.

Using the formula $d_1(km)=4,1(\sqrt{h_1}+\sqrt{h_2})$ where h is the antenna height in meters, you can calculate your the radio horizon. If $h_1=2$ and $h_2=100$ m you get a range of 50 km. If you climb the alps so $h_1=2$ and $h_2=4.000$ m you get 300 km, not much DX even from a super high mountain peak.

In the old days the radio horizon was considered the max distance possible on UHF/SHF. Still many books mentions UHF/SHF as only line of sight communication and many hams only active on FM believe this. Once you have tried SSB you will have realized that a 3-500 km QSO can be made anytime. Clearly some other propagation mechanism than line of sight is responsible for your daily DX QSO's. This is troposcatter.

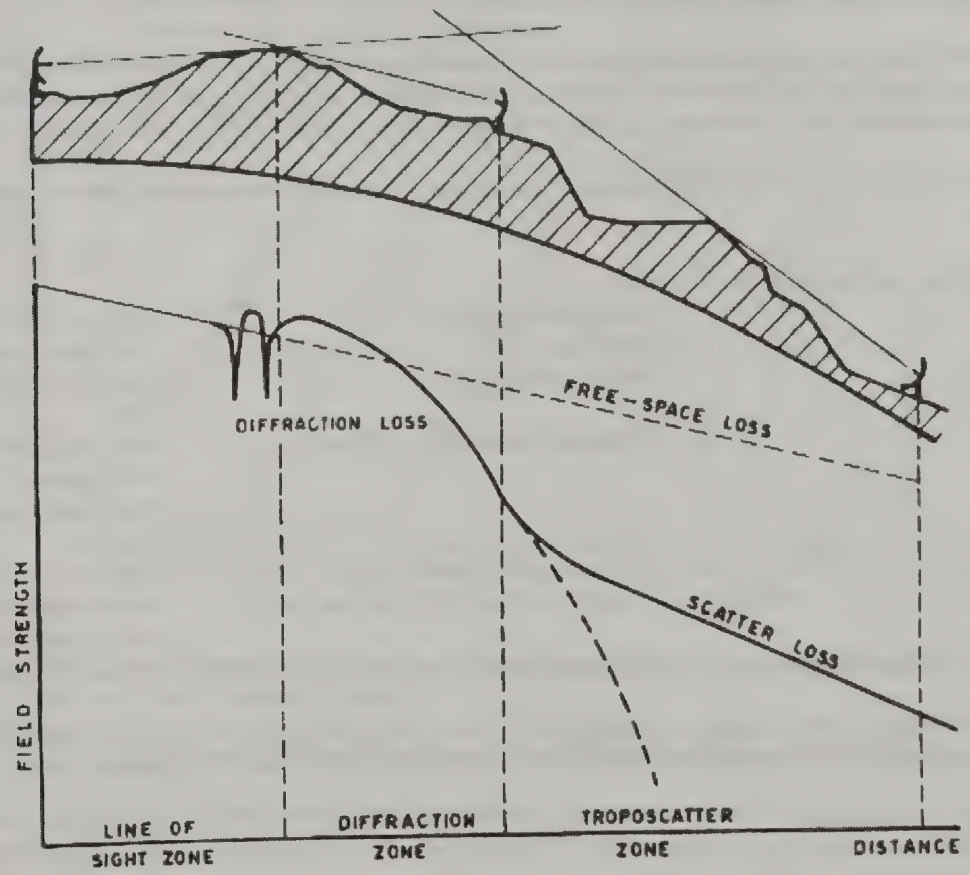


Fig. 1.1 From line of sight to troposcatter.

30-50 km -->I 100 km-->I Real DX >> 1.000 km

Roda Troposcatter Links Fig 1.1

Troposcatter - daily DX!

Troposcatter is spreading of radio waves in the troposphere caused by irregularities in the atmosphere. The troposphere is the atmosphere below an upper limit called the tropopause, which is in a height of app. 10 km. Above the tropopause the temperature is constant, there is little humidity and no movements in the air, thus few irregularities to scatter our radio signals.

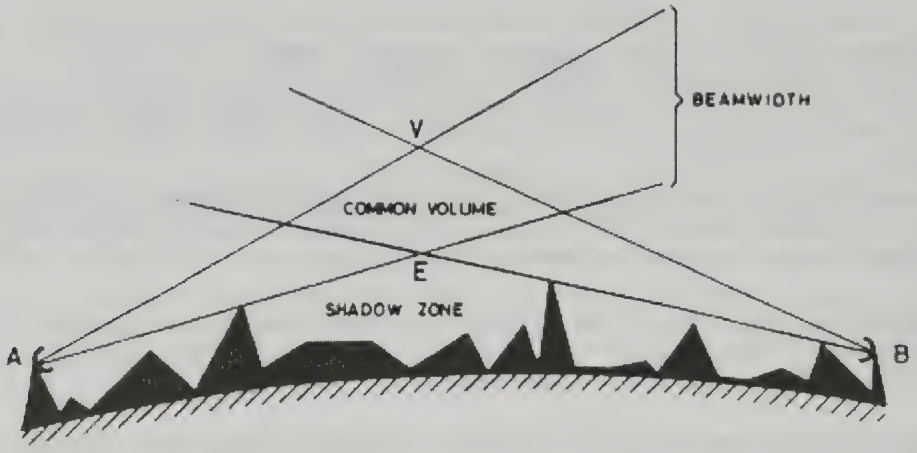


Fig. 4.4 Profile of a typical troposcatter path

Roda, Troposcatter Links

Troposcatter is always present and as we see later independent of frequency from below 144 MHz to 10 GHz.

Troposcatter was used by commercial services and the military 1950-80, so information on troposcatter may have been restricted in those days due to security reasons. Also the required SSB/CW power and beams were not so common among amateurs in those days as today. Thus troposcatter so far remains quite unknown to many amateurs.

To make it worse, the textbooks on troposcatter are written for the commercial world, who has other interests than amateurs.

Important factors regarding troposcatter:

	Commercial interest	Amateur interest
Range	2-400 km	4-800 km for real DX.
Reliability	Over 99,9% wanted	Less than 50% OK for a marginal QSO.
Fading	Reduces bandwidth or bitflow	Only fast fading >50 Hz may degrade intelligence. Slow fading may give QSO in up periods.
Bandwidth	Large, 15-60 phone channels	Small, SSB= 2 kHz, CW=100 Hz
Location	Chose "the best QTH" and pay for it...	Home is home, choosing a good QTH is only possible for /P operation.
Enhanced propagating conditions	Unwanted, means interference problems	Wanted, means more QSO's

Thus the textbooks on how to design troposcatter links describes many factors not too relevant for amateur DX. Today newer text often considers troposcatter as just another source of interference to microwave links.

Path loss, expected range of your station.

Path loss can be calculated to within 1 or 2 dB using the formulas in the textbooks. Lets skip the mathematics and look at the following diagrams. They tell us what to expect from troposcatter on 144 and 432 MHz:

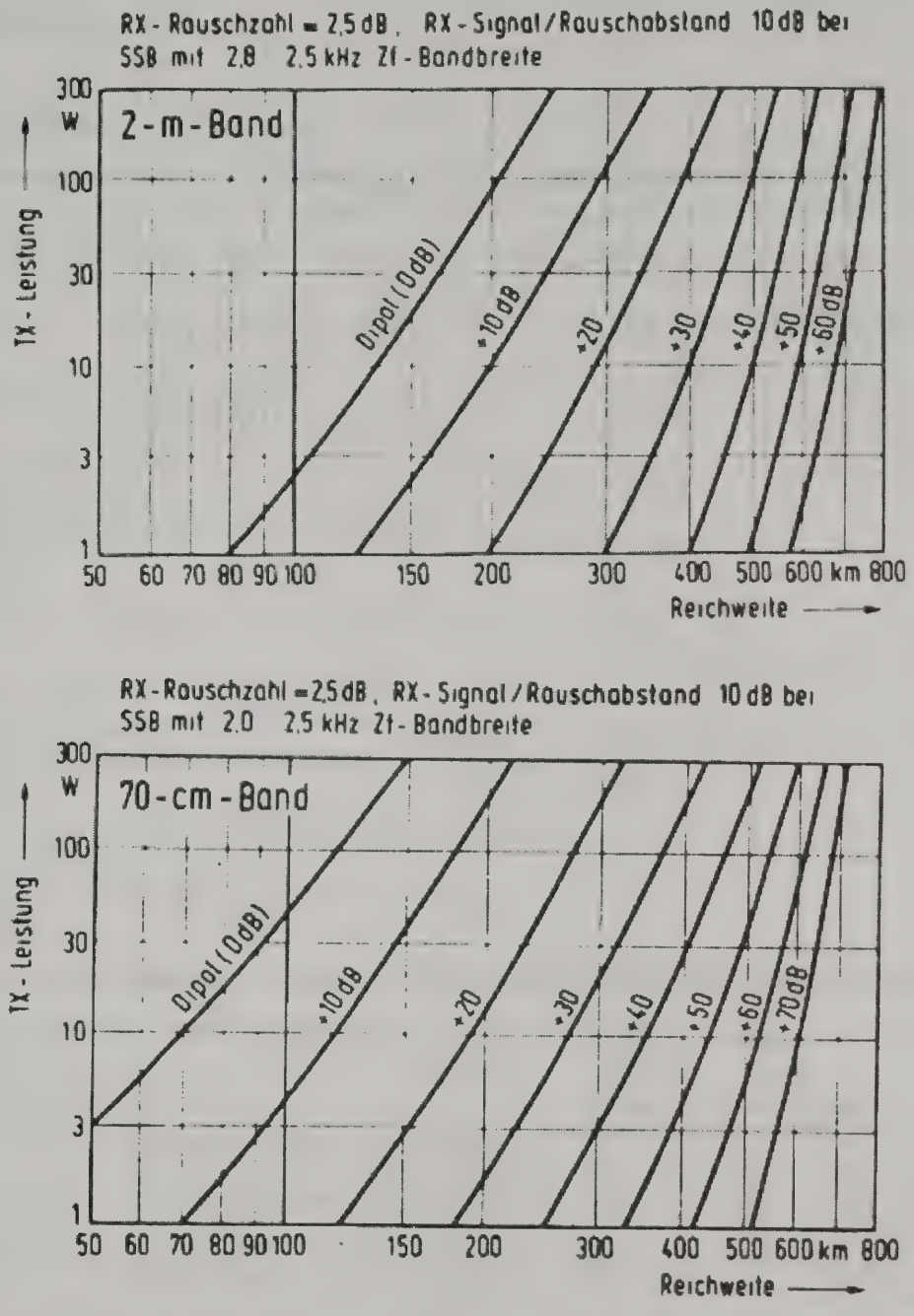


Abb. 21 Diagramme zur Leistungsabschätzung für Scatter-geprägtes Tropo-DX auf 2 m und 70 cm

Gerzelka, UKW-Amateurfunk, 1981, München, IBSN 3-7723-6472-1

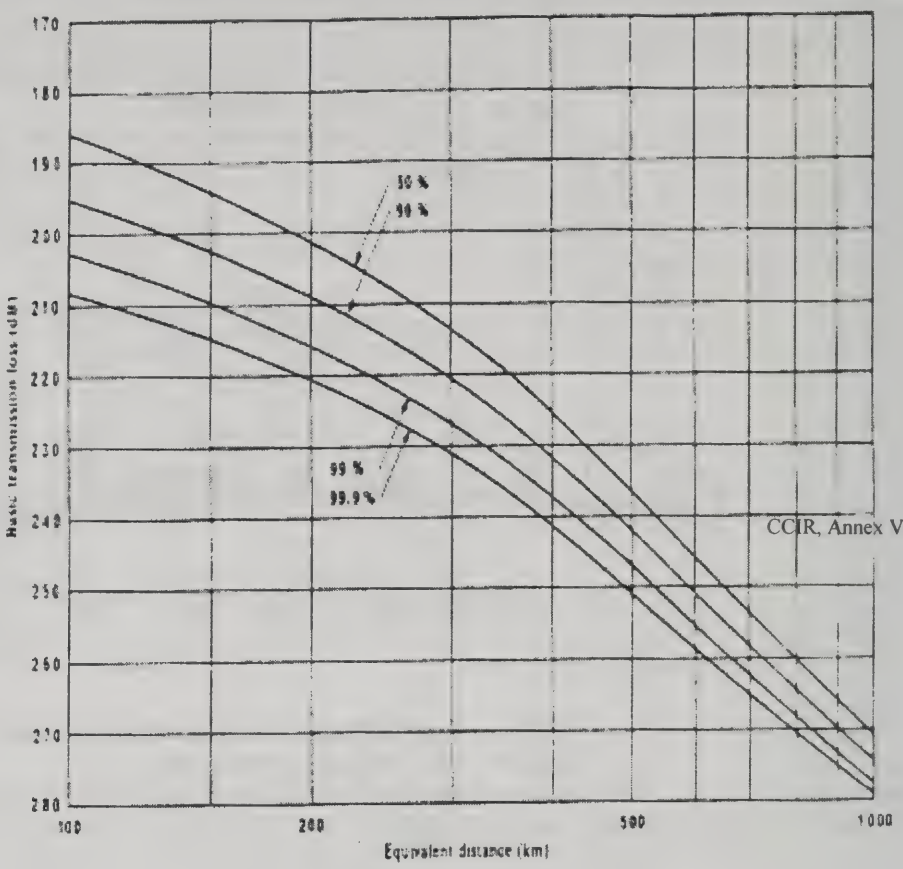
The diagrams were done in 1981 and are conservative, as we today quite easy can have a noise figure better then 2.5 dB in our RX. However the man made noise in cities will most likely be the limiting factor at least on 144 MHz.

The antenna gain shown in the diagrams are the combined gain of the two stations. Suppose you and your QSO-partner only have a small beam with 10 dB gain on 144 MHz the 20 dB curve tells you to expect a range of about 290 km with just 10 watts SSB. On 432 MHz a beam with the same boom length (perhaps 3 meters) will have app. 15 dB gain. Your range on 432 MHz is then seen on the 30 dB curve and is about 270 km. The interesting thing here is that the range is about the same on 432 MHz as on 144 MHz.

Two better equipped stations with a 15 dB antennas and 100 watts will have a range of 500 km on 144 MHz.

Path loss increases app. 10 dB per 100 km for each of the first few 100 km. At longer range the path loss increases with less than 10 dB per 100 km. At temperate climate the 50% path loss for land paths at 1 GHz:

Range	Path loss increases
3-400 km	+11 dB
4-500 km	+10 dB
5-600 km	+9 dB
6-700 km	+7 dB
7-800 km	+6 dB
8-900 km	+5 dB
9-1.000 km	+4 dB



CCIR, Annex V, fig 21

FIGURE 21 – Annual basic transmission loss for tropospheric scatter at 1 GHz
Temperate climate

CCIR, Annex V, fig 21

Troposcatter range of equipment capable of moonbounce operation taken from Radio Communications, August 1981:

MHz	EME path loss dB	Tropo range km	Equipment for EME (in 1981)	Antenna Gain
144	252	990	500 W, 3 dB NF, 100 Hz, 4 x 16 elm	21 dBi
432	262	940	500 W, 3 dB NF, 100 Hz, 20 ft dish	26 dBi
1296	271	890	500 W, 3 dB NF, 100 Hz, 16 ft dish	34 dBi
2304	276	860	100 W, 3 dB NF, 100 Hz, 16 ft dish	40 dBi
10368	289	790	50 W, 3 dB NF, 1 kHz, 12 ft dish	50 dBi

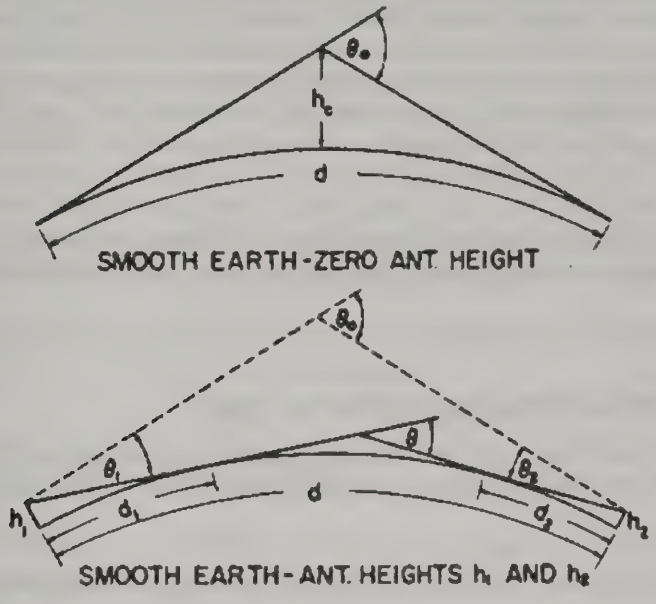
The past 20 years has provided us with low noise transistors, so a noise figure of 1 dB is standard up to at least 10 GHz. The lower noise figure can be utilized better on the higher bands where the noise level is lower. The conclusion is that if you are capable of EME, your troposcatter range is around 900 km on all bands 144 MHz to 10 GHz.

I do not know if there is any limit to troposcatter range as long as power and antenna gain is improved. Some of the curves in the literature on troposcatter path loss go to 1.200 km. In the sixties there were two 400 MHz troposcatter link from Thule, Greenland to Cape Dyer and Baffin Island, a distance of 590 and 625 statute miles, about 1.000 km. On a military budget is was possible to setup 40 m dishes and to run 10-100 kW. For us amateurs we all too soon hit the license limit and/or the limit of our credit card. For most of us this limits our range to around 800 km on troposcatter.

The better equipped eme stations could investigate the maximum range of troposcatter by using modern signal detection techniques like FFTDSP. The most difficult task is likely to have the needed low angle of radiation. Few eme stations have their antenna on a 30-40 m tower or reside on a hilltop, either of which is needed to get really low angle of radiation. Never the less I predict 1.000-1.200 km troposcatter QSO's can be done by the top eme stations anytime with the present day DSP techniques. I would like to hear about results in this direction – you should once in a while try to do something 'impossible' to get experience.

Scatter angle and path loss

The scatter angle should be as small as possible as each degree of scatter angle cost 9-12 dB in signal strength. The scatter angle is directly proportional to the radiation angle used at each station, and increases with increasing angular distance between the stations.



$$\theta_0 = \frac{d}{R}\ \text{RAD} = \frac{180}{\pi}\frac{d}{R}\ \text{DEG.} \quad (1)$$

$$h_0 = \frac{d^2}{8R} \quad (2)$$

$$\theta = (\theta_0 - \theta_1 - \theta_2)\ \text{DEG.}$$

$$= \left(\frac{d - d_1 - d_2}{R}\right)\frac{180}{\pi}\ \text{DEG.} \quad (3)$$

$$d_1 = \sqrt{2Rh_1}\ ;\ d_2 = \sqrt{2Rh_2} \quad (4)$$

(a)

IRE Transactions on Communications Systems, September 1960

A troposcatter QSO is comprised of 3 legs:

- free space loss from your antenna to the horizon: d_1
- scatter loss for the distance: $d - d_1 - d_2$
- free space loss from the horizon to your partners antenna: d_2

The angular distances must be calculated taking refraction into account, that is the effect of the diminishing refractivity of the atmosphere with increasing height causing the radio wave to be bent (refracted) towards the earth. This refraction is also known as 4/3 R, meaning that to radio waves the earth looks flatter, as if its radius were 4/3 of its actual radius.

As you know from satellite communications the free space loss is relatively small, so you want to have as long d_1 and d_2 as possible. That is one of the reasons we climb whatever mountains we may find to do /P operations.

Using the formula $d_1(km)=4{,}1(\sqrt{h_1})$ where h is the antenna height in meters over the horizon, you can calculate the distance to the radio horizon taking refraction into account. This formula gives you:

h_1/h_2 in meters	d_1 in km	h_1/h_2 in meters	d_1 in km
10	13	1.000	130
50	29	2.000	183
100	41	3.000	225
200	58	4.000	259
500	92		

As you can see the distance to the radio horizon is small compared with the wanted 700 km DX even from high mountains. Typically a 700 km troposcatter QSO is done with two legs of line of sight less than 50 km and one scatter leg of 600 km. One conclusion of this is that mountain climbing is not real necessary to work troposcatter DX. As the highest mountains in Denmark are hills of less than 200 m there are still hope for us OZ-contest teams. And the PA0's may go ahead and work DX from sea level. The theory back up the fact that lowlanders can do well in contests.

As the distance between the stations increase the scattering takes place higher and higher in the troposphere. For the longer DX QSO's the lowest part of the scattering volume is several km up. One effect of this is that a high mountain at the midpoint between the two stations has no influence on the signal. Thus troposcatter can span the Alps with no problems as long as both stations has a clear horizontal view to the horizon. So daily transalpine QSO's are no wonder, just troposcatter QSO's.

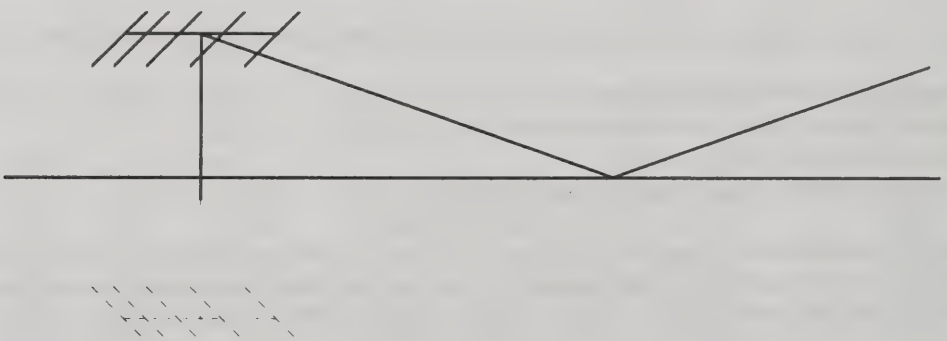
As troposcatter loss increases with the scatter angle you will obviously want to have as small scatter angle as possible. This means that the two radiation angles should be kept as small as ever possible since every degree cost 9-12 dB. If there is a mountain in the direction of the other station you must have a high radiation angle to shoot over the mountain, and this will cost you many dB in signal strength. Even though knife edge diffraction may bring your signal around the mountain, the extra 30-50 dB diffraction loss will prevent you from real DX. You should look for a QTH with a clear view to the horizon at sea level. You may even have a small negative viewing angle to the horizon from a high cliff overlooking the sea.

Let's say you have found such a super QTH. The next problem is to radiate as much power low at the horizon, where the radiation really counts. So lets us examine what determines the radiation angle of your signal, which is the same as your receiving angle.

Radiation angle, ground reflection and ground gain

For DX-ers on HF it is well known that the radiation angle of a *horizontal* beam is a function of its height over the ground. Since our beams at VHF/UHF are horizontal this applies to us, and in the following I only deal with horizontal antennas.

The radiation angle is the angles where the transmitted signal and the signal from the ground image of the antenna are in phase.



Flat Ground

The following radiation angles can be calculated for a QTH on a flat ground:

Beam height over flat ground in meters	432 MHz	144 MHz	50 MHz
10 m	1 °	3 °	9 °
20 m	0,5 °	1,5 °	4 °
30 m	0,3 °	1 °	3 °
40 m	0,25 °	0,7 °	2 °

To have a low radiation angle from a flat ground it requires a tower of 10-15 λ, which is difficult on VHF.

The angle of radiation for horizontal polarization is only dependent of the antenna height over reflecting ground. Using a vertical stack of two horizontal beams will concentrate the energy at the lowest radiation angle determined by the average antenna height, so stacking is recommended, but stacking does not "pull down" the radiation angle. The radiation angle of the stack is the same as from one antenna mounted at the average antenna height, but the stack will put more power (say +2.5 dB) out at this angle. Vertical stacking of two beams will mean the average antenna height will be in the middle of the two beams, that is half the stacking distance lower than the upper beam. This means higher radiation angle than using the upper beam alone. Stacking requires a higher tower in order to get the same angle of radiation. If your situation is a fixed tower height consider, that stacking will mean more power in the lowest loop, which will be at a higher radiation angle than using just one antenna at the top. The net result of stacking two beams relatively low over the ground will be more power below 1 degree where it counts for troposcatter, but not an improvement of the expected 2.5 dB. The net result is dependent of your tower height and the terrain (flat or sloping), so you should do some calculations for your situation. If you want a 2.5 dB improvement for troposcatter and your tower is only a few wavelengths high you might be better off putting up just one beam with the double boom length at the top of your tower. Now you know one of the reasons OZ5W/OZ9EDR uses 2 meter beams with a boom length of over 11 m and why we build a 30 m tower.

Sloping ground

If the terrain is not flat quite a lot may happen to the radiation angle. If you have a hill in front of you, so the terrain is sloping upward the radiation angle will increase, clearly not good. However a downward slope will give lower angle of radiation. The required height of your tower is much smaller, when your QTH is on top of a hill, which is sloping gently right to the ocean or horizon in all direction. This is one of the main reasons for going /P to a hilltop.

If you want to know more on ground reflections, radiation angle and ground gain see my article in Scriptum der Vorträge 1998 p. 21.1-21.11 or at www.qsl.net/oz1rh

Selection of a super QTH

The following are the site requirements mentioned in Roda, Troposcatter Links. If you can get such a QTH, you may have a big signal!

> a variation of 1° in the scatter angle means a variation of about 12 dB in the path loss. Of course on flat terrain (e.g. in the desert) the antenna will be pointing horizontally or, when unavoidable, upwards.
>
> The space in front of the antennas must be clear of all obstructions and the horizon must be at a distance of some kilometers. If there are trees or other obstructions that cannot be removed, the antenna should be mounted on a tower high enough for there to be a clearance equal to at least the radius of the antenna. Care must be taken that there is no manmade radio noise or possibility of interference in the area of the station. There should be no motor roads in front of the antenna, as motor ignition systems generate radio noise. The site requirements are summarized in Table 11.3. The chosen site should provide a sufficient area for the station. Leveling of the terrain could be advisable but it is not often necessary.

Table 11.3 Site requirements

1. Elevated position, the higher the better
2. No obstructions in front of the antennas
3. Horizon distant at least some kilometers
4. No mountains or hills in the direction of the distant station, obliging the antennas to point upwards
5. Horizon possibly depressed with respect to the horizontal plane from the site so that the antennas can be pointed slightly downward
6. No motor roads or other facilities generating radio noise particularly in front of the antennas

CCIR recommends that the antennas should be pointed slightly above the horizon: "The precise optimum elevation is a function of the path and atmospheric conditions, but lies within about 0,2 to 0,6 beam widths above the horizon". It does not sound logical to point the antennas up when we want low angle of radiation. The purpose this beam tilt seems to be to have less noise pickup from the ground at 270 °K and less man made noise. I assume this is only valid at SHF and for shorter distances.

To have a low angle of radiation your antenna must be high above the surrounding reflection ground. 900 m ASL is no good on 144 MHz if your QTH is on a large plateau and your antenna is only 5-10 m AGL. 30 m ASL and 30 AGL is much better. Have you noticed that the PA0's are quite strong?

Even a 900 high peak is not good if there are other peaks of same height or higher surrounding it. The best QTH gives you good ground reflections (+5-6 dB in peaks) and if the ground is sloping down in all directions, it will give you the important low angle of radiation without a monster tower.

What is most important, high up in the mountains or a low angle of radiation? The formula for calculation of path loss on troposcatter does not take height ASL much into account, as this is of minor importance. If you want to climb a mountain top in the alps pick the highest (Mont Blanc, 4.800 m) and remember that you still need the 500++ watts linear and the 15-20 dB array for 144 MHz if you want real DX and to win a contest.

Surely a good height ASL will increase your line of sight and the diffraction zone will reach further out. So what, most signals within 200 km will be 59+ anyway if you are equipped for troposcatter (good TX power and antenna gain). And with only few watts and a small beam not even a mountain peak will bring you much 700+ km DX.

A high QTH is only good, if there are no other mountains around is, which is seldom the case. Even a high QTH needs a high tower to get a low angle of radiation, if the QTH is not on a sharp peak. In order to utilize any low angle radiation you must have a clear view to the horizon at zero or less degrees. If your horizon shows you a mountain your DX will be seriously influenced in that direction.

Another factor is, that during good band condition your mountain peak QTH may be above any possible inversion layer, and then your signal will be reflected into space and wasted.

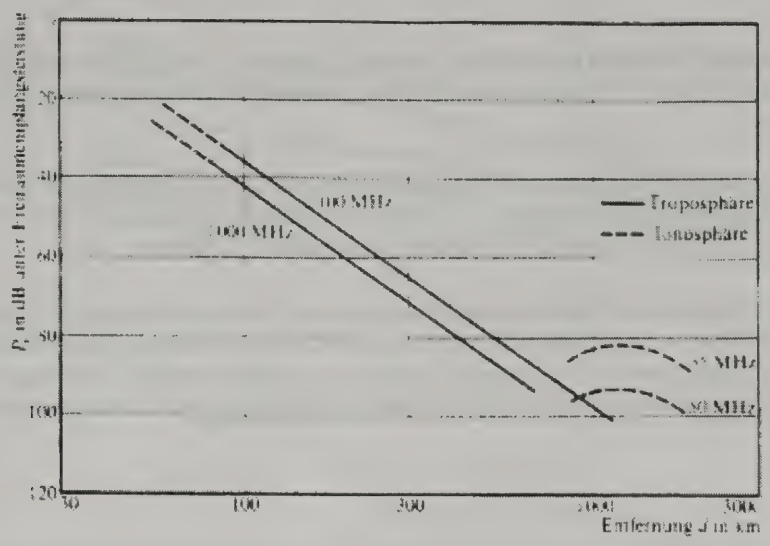
But normally height is no disadvantage provided you have an unobstructed view to the horizon at see level. The conclusion of all this is that the super QTH is high up on a sharp peak with the ocean visible in all directions, no noisy cities, no cars, no TVI, no other amateurs within 1-200 km and with a husky 3-phase main supply for your linear.

Is troposcatter dependent on frequency?

Troposcatter is independent of frequency from 144 MHz to over 10 GHz. At lower frequencies the wavelength is becoming bigger and bigger compared to the typical scatter cells. Above 10 GHz troposcatter is still available, but absorption by oxygen and water vapor in the atmosphere needs to be considered. Even at 10 GHz this absorption is not more than 5 dB at 1.000 km.

Troposcatter will work on 50 MHz also, but few amateurs have the same power and size of antennas as on 144 MHz. Also the atmospheric noise level is higher. On 50 MHz you may consider ionosphere scatter, a similar process caused by scattering of irregularities in the ionosphere at 65-85 km height. This may give you a range of 1.200 km every day, if you can provide 500 watts to a 12 dB antenna.

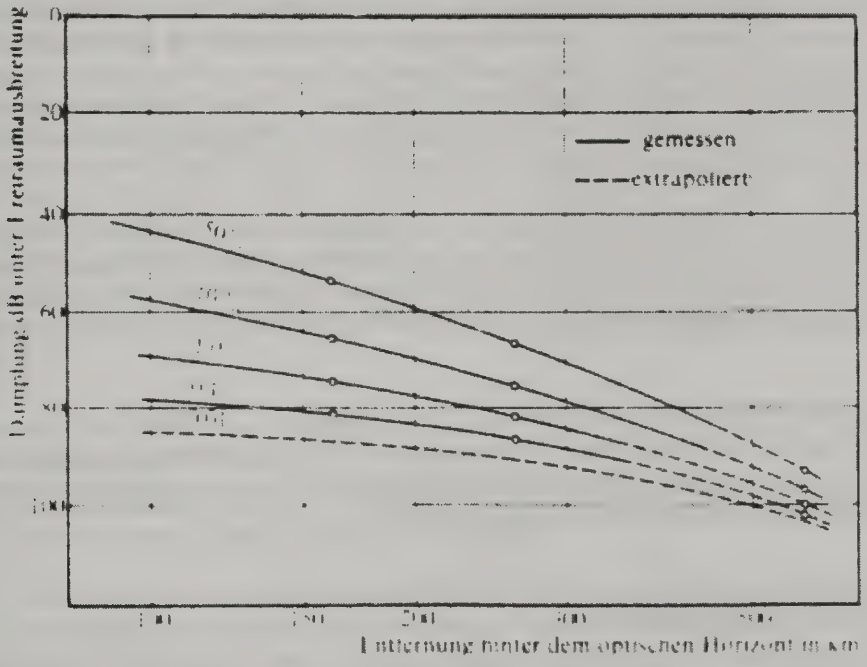
If you are capable of EME on 50 MHz and have your antenna very high up, so you get a low radiation angle, you will experience some very interesting ionoscatter QSO's provided you can find someone in the other end with a similar setup.



53 Streudämpfung in dB unter Freiraum als Funktion der Entfernung [46]

Grosskopf fig 53 p. 165

This diagram shows how many dB the troposcatter path loss is below the free space path loss at various distances from 100 - 3.000 km. For the longer distances ionosphere scatter is included, and this shows us some interesting possibilities on 50 MHz, as this scatter process is also available 24 H all year round.



54 Streudämpfung in dB unter Freiraum für den Frequenzbereich 40 . . . 1000 MHz und verschiedene Zeitprozentsätze

Grosskopf fig 54 p. 165

This diagram shows how many dB the troposcatter path loss is below the free space path loss at various distances from 100-500 km. Also shown is how many percent of the time you can expect a given loss. The diagram is valid from 40 - 1.000 MHz, so troposcatter is also possible on 50 MHz. See Scriptum der Vorträge 1995 or www.qsl.net/oz1rh for a detailed discussion on troposcatter at 50 MHz.

If you have an antenna of same physical size and same power, signal strength on troposcatter will be the same for all frequencies 144 MHz to 10 GHz. Even though the path loss increases with the frequency, the antenna gain increases also. For ranges less than 500 km antenna gain loss will influence signal strength.

On 10 GHz few amateurs have the power on to do troposcatter, but when enough 10 GHz stations run 10 w and a dish a few meter in diameter, they will realize that 300 km+ can be worked anytime also on 10 GHz.

Polarization

Signal polarization is well preserved during troposcatter transmission and transmission loss and signal fading do not depend on which polarization is used. Thus reception with diversity polarization or the use of circular polarization will not help to overcome fading.

As all DX is done with horizontal polarization you must use horizontal polarization in order to work DX using troposcatter. Remember this is also valid for 50 MHz. A vertical is no good for troposcatter DX if the other station has a horizontal beam, which is likely to be the case for a serious troposcatter DX partner.

There is one more problem using vertical polarization for troposcatter. With vertical polarization your antenna will not radiate below the so called Brewster angle which is 10-30 degrees depending on the ground conductivity. Over saltwater the Brewster angle may come down to a few degrees. Since every degree costs 9-12 dB there is little troposcatter DX in a vertical antenna. If you want more knowledge on the Brewster angle read some books on 80 m DX.

Signal quality

Scatter is composed of simultaneous reflections from many small objects. If all the resulting small signals arrive in phase at the RX the scatter is coherent and the signal quality is Q5. If all the small signals arrive more or less out of phase at the RX the scatter process is incoherent and the signal sounds distorted, much like aurora. Tropospheric forward scatter along a great circle bearing is almost coherent, so signal quality is OK as long as we use SSB or CW.

Long distance troposcatter signals has a slight hollow "tropo sound" somewhat similar to a slightly aurora distorted signal. It is caused by incoherent scattering as the scatter angle is increasing. At 700 km the scatter angle is about 5°. We can experience tropospheric side or back scatter when our beams do not point at each other, so the common scatter volume is not along the great circle bearing. This is mostly heard on stations with big (narrow) beams and QRO linears. The backscatter signal sounds distorted, much like aurora (which actually is just 'back scatter from field aligned patches of auroral ionization'). So if you get reports on bad audio it could be caused by tropospheric backscatter, so make sure both beams point at each other before you investigate your audio.

If you want to do high-speed broadband data transmissions via troposcatter you should study the books closely on distortion, bandwidth and diversity reception, but then you are probably an engineer and know it anyway. Should an amateur want a long range troposcatter data link he would probably consider a narrow bandwidth modulation like Pactor II or PSK31 if the needed frequency stability can be provided. Who will be first with a 300 km data link on VHF?

Note that troposcatter works from 50 MHz to 10 GHz (to some extend also on 28 MHz) and in principle the propagation mechanism does not change. However we often find troposcatter to be less on 50 MHz and this is mostly due to the average amateur tower being smaller in wavelengths on 50 MHz than on the higher bands and the fact that the wavelength becomes large compared to the size of the scatter cells.

Fading, diversity reception

Slow fading can be ascribed to overall changes in refractive conditions in the atmosphere. Rapid fading is caused by movements of small-scale irregularities, which are responsible for the scatter process.

The mean fading frequency increases proportional to distance and frequency. The frequency of rapid fading is at:

VHF	few fades per. min.
UHF	few Hertz
12 GHz	>20 Hz during rainfall.

If you are on 10 GHz rainscatter may give you very fast fading (flutter) or distortion.

The fading rate is slower when the hourly median signal strength exceeds the long term median signal level, e.g. slower fading during good conditions.

The best signal strength in temperate climate zones are on summer days. Daily variation are most pronounced in the summer time and on short 1-200 km land paths. Signals here are stronger in the early morning than in the afternoon. Real 700+ km DX has little daily variation in signal strength.

Seasonal variation is also less for real DX:

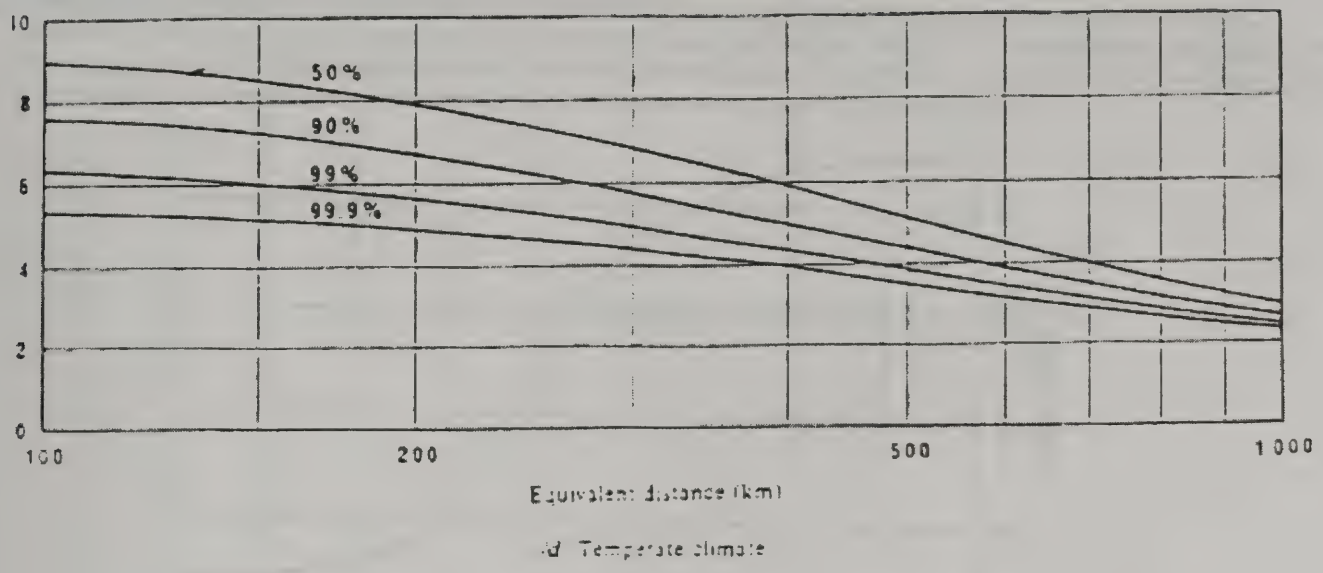


FIGURE 6 – *Curves giving the difference between worst-month basic transmission loss and annual basic transmission loss*

CCIR Annex to Vol. V, 1990, fig 6 p. 427

The commercial world often fights fading with diversity reception, two or more receivers and selection of the best signal. Two antennas spaced 50-100 λ will do the trick, but this seems to be an overkill for most amateurs. It is much easier to wait a few seconds or retransmissions in order to copy the signal.

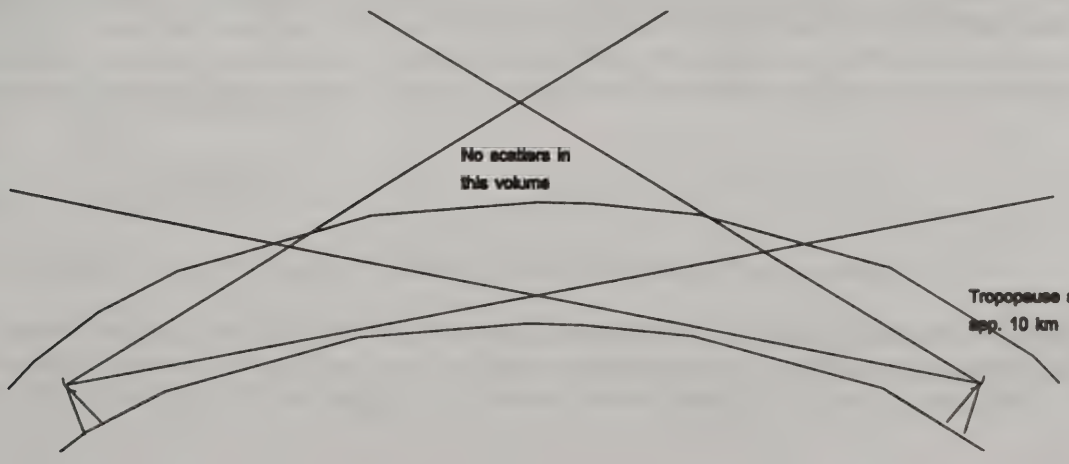
If both you and the other station do not beam directly to each other you may still illuminate a common part of the troposphere with your signal. Given enough power and antenna gain you may experience a side scatter QSO. The signals may then have distortion similar to an aurora tone. Actually all kind of side and backscatter experiences this "auroral" tone. Just try FAI or the real aurora, the latter is really nothing more than backscatter from aurora borealis.

Side scatter troposcatter will be weaker than pointing your beams directly along the great circle bearing. If the other station is not beaming your direction you may experience that the only possible form of QSO is side scatter, so that you also have to beam off the great circle. Signal strengths for side scatter falls off fast, with some 10 dB for each degree off the great circle.

Height of troposphere

One reason for the better summer DX conditions might be more refraction, that is greater radio horizon, due to both more humidity in the warmer air and more temperature gradient.

The height of the troposphere differs between summer and winter and with latitude. This influences our DX possibilities. The tropopause is the upper limit of the troposphere, which contains most of the scatter cells that scatter our radio signals. The higher the tropopause is the higher the scatter cells are found. And the higher the scatter can take place the greater signal strength and longer DX is possible.



One of the reasons to the generally better DX conditions found in the summer months could be due to the higher tropopause at summertime.

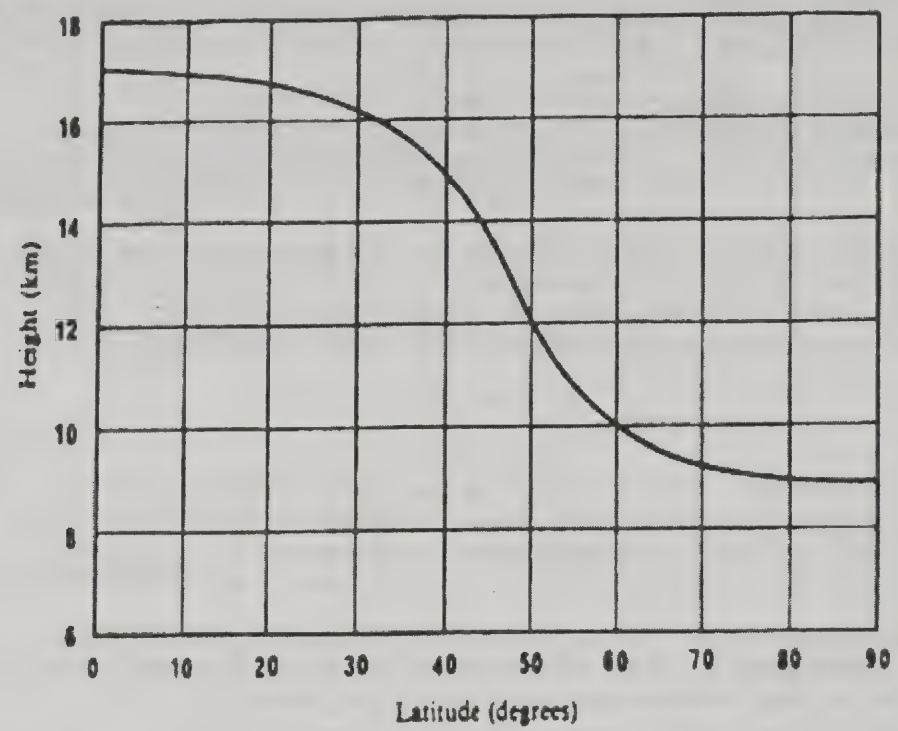


FIGURE 21 - *Variation of summer tropopause height with latitude*

CCIR, Annex to vol. V, p. 141

You see that the troposphere reaches to a height of 17 km near the equator, so expect the best troposcatter conditions in the equatorial zone. This argument is backed by the CCIR curves for path loss in the equatorial zone, but is of little importance, since you hardly are going to let the equator be your next /P QTH.

Much more interesting is the variation of the troposphere height 3-400 km from your QTH. The weather service (MET office) of a major airport near you may provide information on this. What you are looking for is turbulence and irregularities as high up as possible. Jetstreams are strong winds about 10 km up and may just provide this. Also a more dense atmosphere will be able to scatter more, so a high pressure will enhance troposcatter conditions, particularly on the distances shorter than 500 km. Thunderstorms may have cumulus nimbus clouds reaching up to 11-13 km. Perhaps thunderstorms 3-400 km away from you will enhance conditions in that direction? Just do not expect miracles from troposcatter. Other forms of propagation provide miracles.

The most important source of information on the troposphere are MST radars, see a worldwide overview of MST radars at http://www1.tor.ec.gc.ca/armp/king/radar/prof-urls.html There is one in Wales which transmits on 46,5 MHz with 160 kW peak to a 104x104 m antenna with a beam width of 3,3 degrees. Such a radar can measure lots of things in the Mesosphere, Stratosphere and Troposphere (thus the name MST) and most important some of the results are available on the internet, check http://www.aber.ac.uk/~mstradar/ and www.nerc.ac.uk/nss/mst.html The radar pictures shows that the scatter situation is often more complicated than the simple drawing I have presented above. Some of the radars provide an online picture of the ionization 80-90 km above the radar site. Here you can even see Es clouds and other forms of ionization, which could be useful for a QSO. Check http://www.irf.se/mst/MSTlatest.html as an example on this.

No. of scatters => antenna gain loss

The books write about 'antenna gain loss', an effect where more antenna gain may not to increase field strength. Lets us look into this effect in details to see if this applies to us. TS need high power and a big antenna, but not more than 30 dB antenna gain at each end according to the text books.

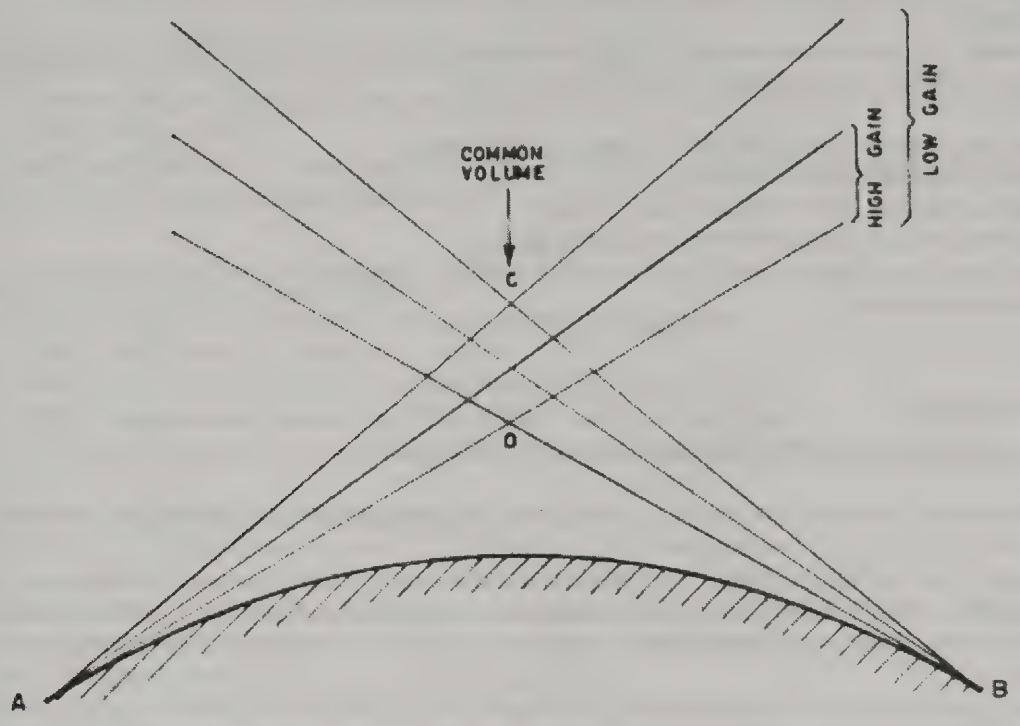


Fig. 4.7 Relation between antenna gain and common volume

High gain antennas will have less common volume of air to scatter the signal. Though the intensity of RF on each scatter cell increases with the square of the beam width, common volume and thus the number of scatters decreases with the cube of the beam width. The net result is, that an increase of 3 dB in antenna gain will not give a 3 dB increase in signal strength if the antenna gain at each end of the path is in the order of 25 to 30 dB or more. This is called antenna gain loss. Few of us have such big antennas for 144 MHz or 432 MHz, but for microwaves more than 30 dB gain is not uncommon. Luckily antenna gain loss decreases as the range increases over 500 km and at 1.000 km there is no antenna gain loss, as only the bottom of the common volume contains scatters. Thus antenna gain loss need not to be considered for real DX.

Airplane reflection or troposcatter

Airplane reflection has nothing to do with troposcatter apart from the fact that you may have difficulty in knowing which propagation mode is providing you with the QSO. It is my experience that some the stations 8-900 km away often pop up on 144 MHz only for 1 or 2 minutes and are then never heard again. This does not apply to the stations I know have eme capability, that is they have QRO and big antennas. They are constantly readable as long as we beam each other.

According to The VHF-UHF DXer, 1992, p.4-8, the signal strength of reflection from one Boing 747 in the right position is at:

300 km	15 dB lower than TS
600 km	as TS
800 km	15 dB higher than TS
950 km	20 dB higher than TS

Could be that quite a few of the longer DX QSO are caused by reflections from airplanes.

I think this table was calculated for 144 MHz. According to the information I have 600 km QSO's can be made on 1296 MHz using airplane reflections with lower path loss than on troposcatter. An example is the regular Copenhagen-Stockholm QSO's made on 1296 during the activity contests which seems to follow the airplane tables.

Greater range on 70 cm than on 2 m

70 cm may have greater range than 2 m, because:

a. lower noise level in the sky means you can take better advantage of a low-noise preamplifier in your 70 cm receiver
b. greater path loss is compensated by a larger antenna gain, given the same physical dimensions of the antenna
c. more frequent ducting because a smaller duct will do

Why do most amateurs then think that 70 cm has shorter range?

1. fewer other amateurs are active
2. greater antenna gain => smaller beam width
3. difficult to have the same transmitter power output
4. in the old days it was more difficult to make a low-noise preamplifier for 70 cm than for 2 m
5. greater cable loss

Conclusion

Troposcatter has the following characteristics at VHF, UHF and SHF:

a) Troposcatter is always there 365 days and nights a year giving propagation possibilities any time.

b) Signal strength is quite reliable, only QSB of some 13 dB on the short distances < 300 km and few dB at 5-900 km. Most QSB on troposcatter takes place on the shorter range, 2-300 km where lifts of 20 dB are not uncommon. The lifts on troposcatter signal strength are often caused by increased refraction, which effectively decreases the scatter angle.

c) Signal strength often +10 dB during summertime or high pressure, most pronounced for the shorter distances < 300 km

d) Path loss increases with about 10 dB pr. 100 km up to 500 km and with some what less at the longer distances

e) The scatter angle should be as small as possible as each degree of scatter angle cost 9-12 dB in signal strength. Since the radiation angle at each end adds to the scatter angle low angle of radiation is very important. Low angle of radiation requires an antenna high over good reflecting ground (>10λ) if the ground is flat.

f) Polarization of the transmitted signal is well preserved

g) Troposcatter is independent of frequency from below 144 MHz to 10 GHz, possibly even from 50 MHz and up. With same power and physical size of antenna you will have same range on all bands from at least 144 MHz to >10 GHz

h) Troposcatter gives you >300 km range day and night all year round with 10 W SSB + beam. Most DX stations will have a range of 7-800 km from an average unobstructed QTH. EME stations can make daily 900-1.000 km troposcatter QSO's with very reliable signal strength.

If there are "good conditions" you will have even longer range with less equipment. Use the many special propagation modes when they are there. There are many possibilities:

Meteorological:	-	inversion	Ionosphere:	-	ionosphere scatter, IS for 50 MHz
	-	ducting		-	sporadic E-skip, E_S
Reflection:	-	earth moon earth, EME		-	aurora
	-	meteor scatter, MS		-	trans equatorial propagation, TEP
	-	airplane reflections		-	field aligned irregularities, FAI
Artificial:	-	satellite transponders			

Literature

8, January 1958, p. 12-18 ← the whole volume is 200 pages of interesting stuff on tropo- and ionoscatter
"Report of JTAC on Radio transmission by ionospheric and tropospheric scatter", Proc. IRE, January 1960
Leang P. Yeh, "Simple Methods for Designing Troposcatter Circuits", IRE Transactions on Communications Systems, September 1960, p. 193-198
W.E. Gordon, "A simple Picture of Tropospheric Radio Scattering", Transactions of the IRE, November 1954, vol. CS-2, Nr 3, p. 97-101
The scatter propagation Issue: Proc. of the IRE, October 1955, p. 1175-1298 ff.
R.G. Merrill, "Optimum Antenna Height for Ionospheric Scatter Communication", IRE Transactions on Communications Systems, March 1960, p. 14-19
R.G. Merrill, "Radiation Pattern in the Lower Ionosphere And Fresnel Zones for Elevated Antennas Over a Spherical Earth", National Bureau of Standards Monograph 38, 1962

Old books:
- Grosskopf, Jürgen (1970), Wellenausbreitung I
- Burrows, W.G. (1968), V.H.F. Radio Wave Propagation in the Troposphere
- David, P. (1969), Propagation of Waves
- E. Baur, Einfürung in die Radartechnik, ISBN 3-519-00106-3, Stuttgart 1985
- **Roda, G (1988), Troposcatter radio links, ISBN 0-89006-293-5** ← quite good
- Reference manual for Telecommunication Engineering, Roger L. Freeman, ISBN 0-471-86753-5, New York 1985

I recommend some works of International Telecommunication Union:
- Reports of the CCIR, 1990, Annex to volume V: Propagation in non-ionized media, ISBN 92-61-04211-2, Geneva 1990 ← comprehensive, some 500 pages!
- **1992 -CCIR Recommendations, Propagation in non-ionized media, ISBN 92-61-04531-6, Geneva 1992, p. 237-245, Propagating prediction techniques and data required for the design of trans-horizon radio-relay systems** ← 9 pages with almost all you need to know about TS!
- **CCIR Study Groups 1990-94, document 5/34-E, Prediction procedure for the evaluation of microwave interference between stations on the surface of the earth at frequencies above about 0.7 GHz**. ← good overview of all kinds of propagation, that gives interference for commercial services and QSO's for us.

Amateur literature:
- **Gannaway, J.N., G3YGF, Radio Communications, August 1981, p. 710-714 and 717.** ← recommended, most amateur literature uses this as source.
- Gerzelka, UKW-Amateurfunk, 1981, München, ISBN 3-7723-6472-1
- The VHF/UHF DX book, 1992, Buckinghamshire, ISBN 0-9520468-0-6
- ARRL UHF and microwave experimenters handbook
- Jessop, G.R., VHF/UHF manual, 1983, ISBN 0-900612-63-0
- Weiner, K., DJ9HO, UHF-Applikation, UKW-Wellenausbreitung. UHF-Unterlage, Teil V.
- http://www.quercus.demon.co.uk/tropo.html <a good site with information on non ducting tropospheric propagation

A little advertising is coming your way also. My practical experience with troposcatter comes from contesting where propagation can be judged. OZ5W/OZ9EDR contest team tries to make DX QSO's regardless of band conditions, but we need someone at the other end to make a QSO. Please try looking for OZ9EDR or OZ5W in major contests and 19-23H local time:

1.st Tuesday of the month:	144.280 SSB/CW +.305 8877/2x8874 2x18elm M2+2/4x9elm
2.nd Tuesday of the month:	432.180 SSB/CW 3CX800A/4CX400A 4x20elm+2x21elm
3.rd Tuesday of the month:	1296.180 SSB/CW OZ1BGZ 70 W at 4x37 elm JO65AP
4.th Tuesday of the month:	50.160 SSB/CW 2x8874 1kW 9elm /P JO55KR

We mostly have one beam to the south (DL and PA0) shortly after 19H local and to the northeast (SM and OH) around 21H local. Please exchange full 6-digit locator. We are in JO55UL or /P likely at JO64GX or JO55KR. Skeds may be arranged even via Email to SMS 40367767@sms.tdm.dk but remember only the Subject field is shown in the SMS.

E-mail: oz1rh@dialip.csc.dk
Phone: +45 46 78 77 67
GSM: +45 40 36 77 67
Fax: +45 46 76 10 67
Sri no packet, life is too short for QRP and 1200 bps!

Snail:
Palle Preben-Hansen
Soderupvej 104
Aagerup Mill
DK-4000 Denmark

© OZ1RH

The K4UHF Award

The K4UHF Award is presented annually to an individual in recognition of exceptional contributions and service to the Society, or VHF/UHF in general. Any member may nominate a candidate by submitting a name and supporting data to the SVHFS President. Final selection of the recipient shall be made by the Board of Directors.

The **1998 K4UHF Award** was presented to **Charles Osborne, WD4MBK** for his many years of promoting the VHF/UHF community.

The **1999 K4UHF Award** was presented to **Steve Kostro, N2CEI** for his achievments in design for the VHF, UHF, and microwave bands.

The **2000 K4UHF Award** will be presented during the Banquet.

Down East Microwave Inc. 954 Route 519 Frenchtown, NJ 08825
Phone: 908-996-3584 (Voice) 908-996-3702 (Fax)

To: All members and attendees of the Annual Southeastern VHF Society Conference.

Subject: 1999 K4UHF Award

Members,

For me personally, to be recognized by one's peers for an award of this stature, is the highest form of compliment that can be achieved. Receiving the 1999 K4UHF award for "Outstanding Contributions and Service to the VHF/UHF Weak-Signal Community" means a lot to myself, to my wife Sandra, and to Down East Microwave Inc., the organization we both own and operate. It says that our "Peers", who are our customers and fellow amateur radio enthusiast that we share this hobby with, truly appreciate what we do for Amateur Radio. For this reason , we are greatly thankful. Without the appreciation of the Weak Signal Community of our capability to produce Amateur Radio products, designs and to stimulate ideas, our efforts would become inconsequential.

There are not many opportunities in this world in which someone can combine their hobby with a means of gainful employment. Both Sandra and I have been most fortunate to have this rare opportunity and treat it as a privilege bestowed to us by the Amateur Radio Weak Signal Community. We both promise to continue providing this service and make a conscious effort in being an asset to the hobby in the years to come.

We both wish the members of the Southeastern VHF Society continued success with the annual conference and the K4UHF award program. We hope that all of your enthusiasm and appreciation of this great hobby, Amateur Radio, continues to propagate and flourish forever. Furthermore, we would like to extend congratulations to all of the future winners of the K4UHF award program. We hope that you will appreciate and relish this recognition as much as we do.

Catch you on the bands and 73,

Steve Kostro, N2CEI
Down East Microwave Inc.

The Southeastern VHF Society wishes to recognize and thank the following companies and organizations for donating prizes for the banquet door prize drawings

ACK Radio
Advanced Receiver Research
Alfa Electronics
Amateur Electronic Supply
Amsat
Andrews Corporation
ARRL
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Coaxial Dynamics
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Tech America
Teletec Corporation
Texas Towers
The RF Connection
Tom Whitted WA8WZG
Timeline, Inc.
Tucson Amateur Packet Radio Corp.

Notes

Welcome!

VHF Weak Signal Group 2000 Banquet

May 19, 2000
Holiday Inn Hotel
Dayton, Ohio

Welcome! Thank you for attending the seventh annual VHF Weak Signal Group banquet. The Weak Signal Group is a group of individuals who are dedicated to the operation of VHF bands 50Mhz and above. We meet every Monday night at 0200 UTC on 3843Khz +/- qrm for the purpose of exchanging information relating to operations in the VHF and UHF spectrum. Net controls are at present Tom, WA8WZG and Herman, N4CH, and Tony WA8RJF. Past net controls were Hal, W4HP and Bryan, WA8MZQ, who were both instrumental in the formation of the Weak Signal Group.

We have a very large gathering of weak signal enthusiasts from the United States and around the world who have come to make new acquaintances or renew old friendships. So, relax and enjoy the magic and camaraderie of VHF weak signal operating. Thank you for attending the 2000 Weak Signal Group banquet.

Weak Signal Group 2000 Banquet

Schedule of Events

6:30 - 7:15 Guest registration and noise figure contest by the Midwest VHF/UHF Society & N8ZM

7:15 - 7:30 Opening remarks and introduction by Tom Whitted, WA8WZG.

7:30 - 8:30 Dinner and Presentation: " QEX and DSP" Doug Smith , ARRL Staff

8:30 - 8:45 Break

8:45 - 9:00 Introduction of prize donors and club officials.

9:00 - 11:00 Prize drawings and fun!

Thanks!!!

Tom Whitted, WA8WZG
Net Control & Planning

Herman Cone, N4CH
Net Control & P.R.

Tony Emanuele, WA8RJF
Reservations & Planning

Matt Whitted, KB8OIU
Registration & Program

Joel Harrison, W5ZN
ARRL Vice President

Tom Holmes, N8ZM
Midwest VHF/UHF Society

Prize Donors

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SSB Electronics
NC1I Contest
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W5UN
KF6DX